THE HUMAN INTEREST LIBRARY

VISUALIZED KNOWLEDGE

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VOLUME I.

CHICAGO

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PUBLISHER'S STATEMENT

ITS PURPOSE

Today — every day — there is something we would like to know and to understand. "Learn one thing every day" might be the legend of The Human Interest Library. Its purpose is to acquaint the reader with the human interest facts of the world's knowledge through his devoting five minutes of spare time each day to interesting reading and to looking at instructive pictures.

ITS METHOD

In order that this knowledge may be acquired agreeably and without special effort, the facts have been woven into gripping human interest stories—stories that give in concise manner and without unnecessary detail, just what everyone wants to know about a famous person, place, picture or event. Each story is complete in itself and can be read in a few moments of spare time. If one story only is read every day, *every day* something worth while will be learned, and the reader will be quite unaware of any effort to acquire knowledge.

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More than a thousand illustrations, selected for their educational and inspirational value; nearly two hundred beautiful full-page engravings and numerous drawings by special artists have been used to fully illustrate all subjects treated and to visualize to a remarkable degree the story of man's achievements. Gathered from all available sources throughout the world, the paintings and photographs reproduced form a veritable picture gallery of the world's great men and great events.

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The volumes now issued are the *basic* volumes of a *cumulative* set of books to which additional volumes are to be added from time to time. Each volume as purchased is complete in itself but so planned as to cover a special field, or to form a distinct part of the whole.

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DESCRIPTION OF CONTENTS

VOLUME ONE

This book concerns many of the commonest things in life about which we, and especially those of us who are children, are continually wondering what the explanation may be. Very often these questions remain unanswered through life; because, perhaps, they are so simple. Here is a very marvelous book in which the ever recurring "Why" is answered. Whether it concerns the mysteries of the body or the far-off wonders of sun, moon and stars, the explanation is equally lucid.

In an age replete with discussion of matters relative to our physical well being, with public interest as never before focussed on physical culture, sex hygiene, eugenics and public sanitation, nothing is more timely than this very Book of Our Own Life. It traces human life from the cell to the full grown man and shows how the tiny microbes, the enemy of man, enter the blood stream, and the havoc they make. How the senses stand guard over the avenue of approach to the body and how the central nervous system from its seat in the brain, guides and directs all, is beautifully told in text and illustration.

Here is a book prepared especially to aid the parent and the teacher. For the pre-school days the book gives a delightful description of Dr. Montessori's system of self-instruction for children. This is followed by courses in other elementary studies to aid the parent in instructing the child when necessarily detained from school. The section on Rural Economy is especially adapted to rural and suburban districts. Home life in the country has never been surpassed in natural environment. It is the problem of today to enhance it still more by enlarging its educational and cultural opportunities; by utilizing every product of invention and science for the improvement of scientific agriculture, horticulture, stock raising and the domestic arts; by providing an improved system of rural banking and credits; and by affording new facilities for the distribution and marketing of farm products.

The many things a boy or girl wants to do, whether work or amusement, is provided for here: carpentry, wood carving, kites, flying machines, telephones, etc., for boys; sewing, millinery and fancy work, for girls; and stories, plays, games, puzzles, private theatricals and magic for all. The section on stories and plays is replete with fancy, anecdote, moral, description, episode and dramatic settings intended to appeal to the imagination and moral sense of children. The play instincts of children are so evident that it seems superfluous to argue the need of proper material in story and dramatic form to keep pace with the growth and expansion of the child mind. The world of childhood is peopled with fairies, myths, flowers, animals, ogres, and wonderful characters at once humorous-pathetic, cruel and kind.

LIST OF ILLUSTRATIONS IN VOLUME I

FULL PAGE COLOR PLATES

FULL PAGE ENGRAVINGS AND DRAWINGS

AND 110 ADDITIONAL TEXT ILLUSTRATIONS

THE ARCHER, A SPORTSMAN AMONG FISHES

Although there may be worms in abundance on the river bottom, the archer prefers to shoot down flies and other small creatures from the bank by means of a series of well-aimed "bullets" of water, which it ejects in rapid succession.

THE BATTLE OF THE PYGMIES AND THE STORKS

Homer and other ancient writers frequently refer to pygmy races which they represent as waging desperate warfare with the storks that came to raid their crops. Recently various expeditions have proved their existence in several parts of the globe.

The Everyday Wonder Book

WONDERS OF THE HUMAN BODY
WONDERS OF ANIMALS AND PLANTS
WONDERS OF LIGHT AND SOUND
WONDERS OF AIR, FIRE AND WATER
WONDERS OF EARTH, SUN AND STARS
THE CHILDREN'S "WHYS" AND "HOWS"
MISCELLANEOUS QUESTION-BOX

An enormously magnified image of the observer, cast upon a bank of mist, is sometimes seen in high mountain regions when the sun is low in the heavens and the observer is between the cloud bank and the sun; it is seen oftenest in the Harz Mountains, Germany.

THE REASON WHY

We are asking questions continually; all our lives we keep saying, "I Wonder Why." Where does the day begin? How do I remember? What makes the rainbow? To all of us come such questions, and as long as we live, such questions will come, however wise we grow. The questions will never stop as long as the world lasts, because out of the answer to one question another arises; and so, all over the world and down the ages of time, grown-ups and children have been saying, "I Wonder Why." All through these volumes we shall find the answers to our questions, but in this especial Book we shall find questions about many things which we particularly want to know. First of all, we learn how the world was peopled; then, how nations lived; how men know things that happened long ago, and how they gathered up the knowledge that is in the world. Later follows the answers to the puzzling workings of our own bodies, and the multitude of questions that come up from day to day about animals and plants; light and sound; air, fire and water; earth, sun and stars; and numerous other things we want to know about.

HOW THE WORLD WAS PEOPLED

IN the childhood of the world, there were not nearly so many people on the earth as there are today. We cannot tell exactly what happened then, because it is so very long ago; but we can make believe that all the people lived in one small part of the world all by themselves. They were like a big family living together in the same house. By-and-by the family grew bigger; more boys and girls began to come, and at last the house became too small for them to live in. So some of them had to go out and find another home. They wandered up and down over the earth, and when any of them found a comfortable place to live in, there they stopped and settled.

So, we are all one big family, and though now some nations seem very different from others, yet they are each some relation to the other, brother or sister, or cousin, or something. This is why we find so many of the same words used by different nations; the words father and mother, for instance, are alike in many different languages.

NATIONS LIVE AND DIE AND PASS AWAY AS YOU AND I

Some of these early nations have died, but others are still living today; for nations, just as we do, are born, grow up, and die, only it takes them a great deal longer time than it takes us. And perhaps some of the nations that are alive today will die and pass away some time in the future.

You may have wondered how we know about what happened long ago, before there were any books or newspapers, even before there was writing of any sort. It is quite easy to find out what happened only a hundred years ago, because there are plenty of books that will tell us all about it. But what about things that happened thousands of years ago?

How we know the story of the world

The boys and girls who lived long ago were just as fond of stories as the children of today. They, too, would ask for stories; and when they grew up, they, too, would tell these stories to their children. So the stories came down to us, right from the earliest time, when there was no reading or writing, but simply story-telling. That is the first way in which we know what happened far back. Boys and girls have been among the most important people in handing on to us our story of the world. What a great loss it would have been if those boys and girls who lived once upon a time had forgotten the stories that were told them!

The next way of finding out what happened long ago is by reading the earliest books. What do you think these books were? Not books such as we have now, but bricks; just clay bricks, with writing and pictures marked on them while the clay was soft, and then baked hard in the heat of the sun. Thousands of these bricks have been dug out of the earth at Babylon and other places. When these cities were destroyed long ago, they became gradually covered with earth; the houses, the streets, the libraries, and everything in them were buried under the ground. And down under the ground these bricks have been kept dry and clean and fresh, and so today we are able to read the writing and the pictures, and find out what the people in those days were doing.

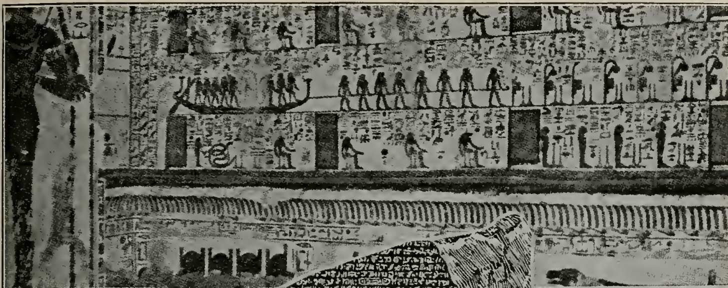
In ancient times, also, when a king did anything of which he was very proud, such as conquering his enemies and taking them captive, he had an account of it carved on a big stone or pillar, and set it up so that people could read all about what he had done. Thousands of these monuments have been found, and there probably are thousands still buried in Egypt, and parts of Asia. The writing on these stones looks very strange to us. Most of those found in Egypt have pictures upon them, instead of words and letters. When you are in New York, you should visit Central Park and look at the tall column called Cleopatra's Needle. This was brought from Egypt, and is covered with pictures; we call these pictures hieroglyphics, which means sacred carvings. When the first of these old pillars was found, no one could read the writing or understand the pictures. It was like a hard riddle.

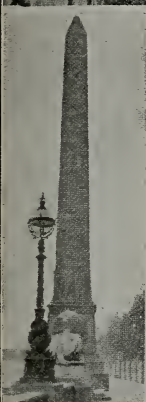
At last, when all the learned men were very nearly giving up the riddle, a great piece of good fortune happened. Some French officers who were in Egypt about a hundred years ago, in 1799, happened to dig up a stone with writing on it, and, to their great delight, the writing was in three languages. One of these was the picture writing, and another was Greek. Now, it was easy enough to read the Greek, and when they had made out what that meant they guessed that the picture writing would mean just the same thing. And so it did. That gave people the key to the riddle, and the whole mystery was made clear. They found that an eagle stood for the letter *a*, a leg and foot for *b*, a serpent with horns for *f*, a hand for *t*, an owl for *m*, a chicken for *u*, and so on. A man with his hands lifted up meant *prayer*.

After reading this one stone, it was easy to read all the other writings on stones and pillars found in Egypt.

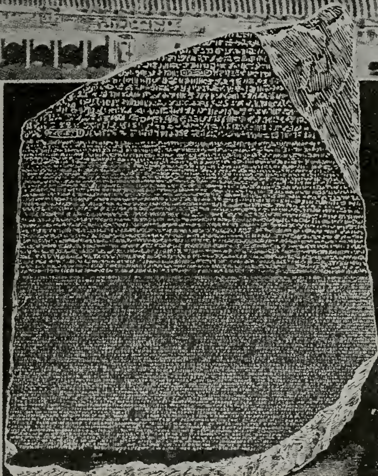
HOW THE WORLD'S STORY WAS FIRST TOLD

The Egyptians painted the walls of their temples and tombs with strange letters and pictures which tell the history of Egypt. This is from the wall of a tomb where the paint is still fresh, though it is thousands of years old.



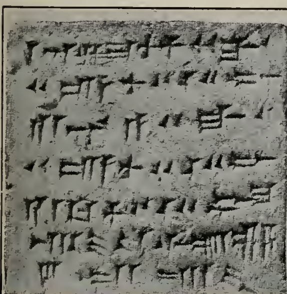


Cleopatra's Needle, once in Egypt, and now standing in Central Park, New York, shows the strange writing on the Egyptian monuments.

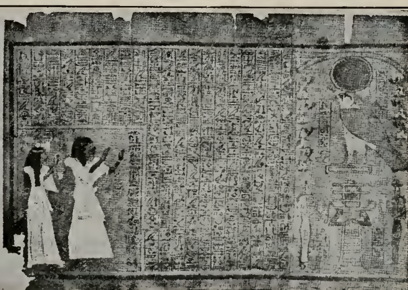


The Rosetta Stone, which taught us to read the strange writing the Egyptians left behind. It said the same thing in three kinds of writing, and one kind was the Egyptian. Men knew one of the other kinds of writing, so that they were able to find out what the Egyptian writing meant.

There was no paper in old Egypt, and the people wrote on bricks and on the dried bark of the papyrus plant, here shown growing.



An early way of writing was to mark soft clay and bake it into a brick like this.



This is a piece of papyrus, showing how the Egyptians used it to write upon. Nearly all these things are in the British Museum.

This precious stone is known as the Rosetta Stone, because it was found at a place called Rosetta, and it can now be seen in the British Museum in London.

Another way in which we are finding out a great deal about early times is by the opening up of many tombs underground, especially in Egypt.

All kinds of things used to be buried with people in those days; so dry and air-tight were the tombs that everything in them has been wonderfully well preserved. Dolls have been found buried with the little girls who played with them long before Moses lived; a baby's rattle that amused a tiny brown Egyptian baby when Joseph was in Egypt; ladies' combs and mirrors, gold ornaments, and jewelry, worn perhaps when the Children of Israel were passing through the Red Sea. And so, little by little, we are finding out what life was like in the old days, and are piecing together the different bits of knowledge that we pick up, just as you put together the pieces of a puzzle to make the whole.

There is one more way in which we are being helped to do this, and that is by finding buried cities and towns just as they were hundreds of years ago. In parts of Asia, such as at Babylon, men are digging out whole towns that disappeared thousands of years ago.

It is well to remember that nothing happens by chance. There is a reason and a cause for everything. If we are wise enough we shall find out why we live and how we are related to one another. For we are really one big family; or we may say that the different nations are like the beads on a string—each bead is different and separate, but they are all joined together by the same string. Through all the story of the world we find this string joining up the beads; through it all we find some plan at work, and see God's hand in its guidance and control.

WONDERS OF THE HUMAN BODY

Why we go to sleep

WE GO to sleep so as to rest. The whole body rests when asleep, more or less—the brain, the heart, the lungs, the muscles, stomach and all. Children want a lot of sleep because children have to grow, and they do most of their growing during sleep; so if they will not go to bed they will not grow properly. Sleep is more important for children than for anyone else, just for this reason, though no one can get on without it. Many of the people who grow up too small or weak, or poor in their minds, are people who did not sleep enough when they were children. Time was when older people were careless about children's sleep, but one of the happiest and best things for children nowadays is that their sleep is looked after.

Where we go in our sleep

We do not go anywhere. We are still there, only we are not awake. That means that we are not awake to what is around us; but though we take no notice of what is about us, we are still there; and even while we are fast asleep we are often doing all sorts of things, or, rather, we think we are.

This is so every time we have a dream, and we have far more dreams than we remember when we wake. Long ago savages used to think that men merely went away somewhere when they slept, and dreaming was one of the reasons that made them think so; but now we are sure that that was a mistake.

Dreams do people all sorts of harm if they are not sensible about them; but we must be sensible, and not think that terrible things are going to happen. Dreams show that we have not really gone away, because they are almost always due to something disturbing us, and nothing could disturb us if we were not there, could it?

So slight a thing as the wind in the chimney, or a leaf tapping on the window-pane, may make us dream. But the commonest thing that disturbs us is our stomach. If we eat too much before we go to sleep, and especially if we eat things that do not agree with us, then in the night they disturb the brain, and make part of it wake up, though not so much as to make us know where we are. So, also, noises often make us dream because they disturb the brain. But sounds could not disturb the brain if we were not still there to hear them.

Why you laugh

You laugh because you are "made that way." Perhaps you do not think much of it, but that is the real answer. It depends upon the way in which your brain and body are built. After all, you laugh when you are tickled, even though you may not be pleased, and that is really easier to explain. If a bright light suddenly strikes your eye, you shut it because your brain is made so as to make you reply in that way.

That is a simple way of replying. And laughing when you are tickled is really the same, only that instead of doing just one thing, you do a number of things all at once. You move many muscles of your face instead of merely moving the muscles of your eyelids. You also move the muscles that you breathe with, in an unusual way, and also the muscles that you make sounds with. It is this particular movement of all these muscles together that we call laughter, and it is really a reply to the tickling, just as drawing away your foot is a reply when someone tickles the sole of it.

Why you cry

You cry because your brain is made so as to act that way. We do not know why your brain should be so made, for though there is much use in tears when we are not crying, yet there is no real use in crying when we are hurt.

When people grow older they find this out, and usually they do not cry when they are hurt. The highest part of the brain—where people themselves really live—is the master of the lower part of the brain, and can order it to do things, and forbid it to do things, as it likes.

Now, it is the lower part of the brain that replies by crying when we are hurt, so that even the tiniest baby can cry perfectly. But when we grow older we tell the lower part of the brain that it must not do as it feels inclined to do, and so we stop crying.

Why the tears come

There is no good reason why tears should come when you cry, but there is a very good and beautiful reason for the tears which we are really making all the time that we are awake, though we know nothing about it. You know quite well that every few seconds you wink both your eyelids at once. You do not do it on purpose, but you do it all the same. If you purposely stop doing it, as people often do when they stare at each other, your eye becomes very uncomfortable, and if you did not wink at all your eye would soon cease to work properly.

What winking does for the eye

When the eye is open, the front of it is exposed to dust and dirt, and also the front of it is apt to get dry, and if it did we could not see properly. Yet how is it that, though we never wash the front of our eyes, they are always clean? It is because we wash them every time we wink. Up above each eye, rather to the outer side, there is a tiny little duct called the tear-gland, and all the time we are awake this is slowly making tears. Then, when the front of the eye feels itself becoming rather dry, and perhaps a little dusty, it tells the brain, and down comes the eyelid for a second, with a tear inside it, and so washes clean the front of the eye. It is the most gentle and perfect washing in the world.

Where the Tears Go

Well, if you look at the inner corner of your lower eyelid you will see a tiny little opening. The tear runs down this and finds itself—where do you think? Now, I will give you a hint before I tell you. When you have been crying a great deal, do you not have to blow your nose? The reason is that the tears, as many of them as can, run down into the nose. All the time we are awake and not crying, this goes on, keeping our eyes moist and perfectly clean, and costing us no trouble. But when we cry we make far more tears than we need. Indeed, we make so many that they cannot even all run down into the nose, though many of them do. So, as there is nowhere else for them to go, and the eye itself cannot hold them all as they come pouring into it, they are spilled over the edge of the lower eyelid, and run down our cheeks.

But, though the tears, when we are not crying, are so useful that we could not do without them, and though the way they are made and used by the upper eyelid when we wink is one of the most beautiful things in the body, yet it is no use to make too many of them. Indeed, though the real use of tears is to make us see properly, you know very well that when you cry you make so many tears that you cannot see clearly at all.

What Wakes Us Up in the Morning

We do not sleep in just the same way all through the night. To begin with, we sleep deeply. Now, it is good to sleep deeply. It makes us look well and beautiful, and people seem to have noticed this, since they call the first hours of sleep "the beauty sleep." But for some hours after this we sleep less and less deeply. We can easily find this out by noticing exactly how loud a noise is required to wake anybody up at various times in his sleep. And we find that when he has had nearly enough sleep he will be wakened by a little noise which, a few hours before, he would not have noticed at all.

Now, that is the sort of thing that happens when we wake. We have been sleeping less and less deeply for some time, and our brain has almost awakened of itself. Then there comes a sound or a light, or perhaps we move in bed and feel ourselves moving, and since we are already very nearly awake, the sound or the light or the feeling wakes us up. Of course, we live in a way that we have made for ourselves; but if we lived out of doors, as men did long ago, and as birds do now, it would naturally be light that woke us up at last. That is what wakes the birds up now. When the sun rises, and the light gets stronger, it wakes them up, though we are awakened by a noise.

Do Our Eyes Deceive Us?

Sometimes we can learn from the deception of our senses. Our eyes see things for a tiny fraction of a second after they are gone. For instance, if you spin a little black and white disk you see circles instead of little bits of circles. That is because the eye goes on seeing even when the lines are not there, and sees until they come round again. So if you take a card with a gate drawn on one side, and a man on a horse on the other side, and spin it, you seem to see the horse jumping the gate. It is this trick of the eye that is used in the biograph or cinematograph.

How a coat keeps us warm

A coat does not make us warm, but all that any coat can do is to keep us warm. Except when the sun is actually shining upon us, or when we are huddling over a fire, we make all our warmth for ourselves. There is no warmth in a coat or in any article of clothing. So, of course, clothing cannot make us warm—unless, indeed, we hold it in front of the fire until it is hot, and then put it on. Indeed, when you come to think of it, we make our clothes warm. Our clothes often feel quite cold when we put them on, but when we take them off they are warm, and they have received the warmth from our bodies.

How clothes keep ice cold

The best way to understand how clothes keep us warm is to learn how to keep ice cold. Well, if clothing is simply something that keeps back heat, as a blind keeps back light, what would happen if we put some clothing on the ice? If we choose nice warm clothing—which simply means that it keeps us warm—ought it not to keep the heat from outside from getting into the ice?

Now, that is exactly what happens. If we take the warmest kind of clothing that we can think of, which is flannel, and if we wrap the ice up in flannel, we keep the ice cool, and prevent it from melting. Now, do you not think that is rather funny? When we want to keep ourselves warm we put on warm clothing, as we call it; and when we want to keep ice cold we put warm clothing on it. Would you not almost have thought that the clothing which made us warm would make the ice warm too, and so make it melt? Well, so it would if the clothing were really warm, like a hot bottle. But then, you see, there is no warmth in it at all.

Why some clothes are warmer than others

You know what a thermometer is. It is something that measures how hot things are. Now, if you take a piece of flannel and a piece of linen that have both been in the same room for some time, and with a thermometer you try to find out how hot they are, you find that they are both just of the same temperature. But on a cold day you would rather put on flannel than linen, because, as we say, the flannel is so much warmer. Yet, according to the thermometer, the flannel and the linen are each just as warm as the other.

What is the meaning of this puzzle? It is simply that some things are better barriers to heat, and keep heat back better, than others.

Why some things are colder than others

In an ordinary room without a fire all the different things are equally as warm, because, if it has time enough, the warmth will spread itself over everything about it, running from anything that started warmer to anything that started cooler.

Yet if you go and touch several of the things in the room, one after the other, you find that they feel very different as you touch them. A thing like the fender will feel cold; the carpet will feel warm; wood would feel colder than the carpet, but warmer than the fender. Now, that is simply because these things differ in their power of keeping heat from running through them, just as flannel and linen differ. The brass of the fender lets heat run through it quickly, but the carpet lets heat run through it slowly, and so we say that the fender feels cold and the carpet feels warm, just as a linen sheet feels chilly when we get into bed, while a woollen blanket feels warm. If a thing carries heat quickly away from our finger, it makes our finger cold, and we say that the thing is cold; and we call another thing warm in comparison with it, if that other thing, like flannel, only carries away the heat from our finger slowly.

What happens when anyone faints

Fainting is really a wonderful thing. What happens is that the heart does not send enough blood to the brain, and so the brain stops working, and the person drops to the ground. When you are standing or sitting, your heart has to drive the blood upwards to your brain against the attraction of the whole earth, which tries to pull everything down. But directly the fainting person falls, the heart's task of sending sufficient blood to the brain is made easy, and so very soon his brain gets sufficient blood, and he "comes round," as we say. If his heart has not been actually strained he is all right again. So you see that the falling is Nature's method of "relieving the situation."

People who have not learned this try to raise up the fallen person, which is simply interfering with Nature's way and putting his brain in the worst possible position for getting the amount of blood it needs. The feet of a fainting person should be raised to allow the blood to more freely reach the brain.

Does the brain need food?

The brain is made of nerves and nerve-cells. These taken together we call nervous tissue, and we know that nervous tissue is more richly supplied with blood than any other tissue in the body, not even excepting the muscle tissue of the heart itself. The blood carries the food materials without which nerve tissue cannot act, and nerve tissue has practically no reserve at all of food supply in it. If the supply of blood is stopped for a moment, nervous tissue "gives out" sooner than any other tissue in the body.

A simple and wonderful little experiment will show you this for yourself. The screen or curtain at the back of your eye, which receives the rays of light from everything you see, is made of nervous tissue. It is packed with blood-vessels. If you shut one eye and look out of the other, and then press your finger firmly on the open eye (pressing on it through the lid), in a few seconds everything will grow quite dark. The eye is open and there is plenty of light, but it is quite blind. Move your finger away and in a second or two you will see again. The reason is that when you pressed on your eye-ball you prevented the blood running through the screen or curtain at the back of the eye, and after about two seconds, during which it was using up what it had taken from the blood, it could do no more, and your eye became blind.

Why we get out of breath

We know that if we treat the heart properly it never gets tired. But if we run very hard, or swim very hard, or do anything of that kind, we suddenly throw a great deal of extra work upon the heart. Now, so long as we are well, one of the most wonderful things about the heart is the amount of reserve power which it is able to call upon at a moment's notice. When we get out of breath we have already called upon this reserve power, and should take warning.

Why we have lines on our hands

Some people have said that the use of these lines is to give us a better hold upon things, but probably that is not their real use. If it were so we should really have to say that they were scarcely worth having. It is much more likely that the use of these lines is to help the sense of touch in our hands and fingers, where touch is so very important. By making little valleys and ridges they increase the surface of the skin, and by going in different directions they help us to feel the kind of surface that anything has which we touch. The little endings of the nerves of touch are placed to the greatest advantage by means of these lines, and that seems to be the reason why they are so very well marked on just those parts of the skin where delicacy of touch is most important.

What is the best cure for fatigue

We must not take a large meal when we are tired, because we are not then fit to deal with food. We may take water, or lemonade, or oranges, because water, in passing through the body, always carries all sorts of poisons away with it and helps us to get rid of them.

But, above all, we must rest, and there is no kind of rest which can be compared with sleep. In general, the people who sleep best are those who work hard. The man who works all day in the fields usually has the best sleep in the world, far better than some unfortunate people who do little or nothing, and who may even take medicine to help them to sleep. Nature, the best of all doctors, has her own medicine to procure good sleep for every healthy person who works; and the most beautiful thing about tiredness, when it is the right fatigue that everyone should feel when he goes to bed, is that it produces in our blood just the very thing that gives us perfect and natural sleep.

Why we have ten fingers

Nature decided on five fingers, or toes, at the end of each limb very long ago indeed—ages before man appeared upon the earth at all. It is true that, at first sight, there seem to be many exceptions to this. We find only one obvious finger, or toe, for each limb in the horse, two for the pig, and so on. But the original figure was five. The hen, for instance, has only three and a half toes, and when we examine the skeleton of its wing—which is really its arm—we find three and a half fingers there. The chicken, as we see it, is the same. But if we examine the hen's egg before the chicken is ready to break through the shell, we find that it has five fingers, or toes, on the end of each of its four limbs; only the birds have apparently found that they could do as well with three and part of a fourth, so they have stopped developing the rest. We must go far below the the mammals or the birds, or even the reptiles, for the beginnings of the five-fingered or five-toed arrangement, and it is not till we study the still humbler creatures that we get to the real beginning. If we look at a frog we can see that it has five fingers and five toes just as we have. So we may say that it was the frog, or the remote ancestors of the frog, which decided ages ago that we should count in tens!

Why all our fingers are not the same length

It might be very difficult to answer this question if we had only the present use of the hand to account for; and it is a disadvantage to us that our little fingers and ring-fingers, for instance, are so short and weak, for this weakens our grasp for things, which is the principle purpose of which we use our hands. Also, this inequality of the fingers in length and strength is a difficulty for the pianist and the typist. We therefore cannot hope to answer this question by referring to the usefulness of the hand for its present purpose. But we find the answer when we consider the history of the hand, and when we look at the fingers of many kinds of lower animals which have fingers more or less like ours.

We learn that our hands were originally used for standing and for walking, since we inherit them from "four-footed ancestors." If we put the hand on a table, as if we meant to walk on the tips of the fingers, I think we shall see at once what a well-balanced support it makes, just because the fingers are unequal in length —the middle finger the longest, and the short thumb and little finger falling behind and balancing the whole. We see the same thing in the case of animals that have three fingers—as the toes of the forefeet might rightly be called—and we can notice it for ourselves any day in the dog or the cat. This is only one instance of a very large number furnished by our bodies which helps us to understand why certain things, for which we can find no particular reason now, and which may even be inconvenient to us, are as they are.

Why we have finger-nails and toe-nails

Perhaps we may think that, at any rate, there is a use for finger-nails, as we can use them to scratch with; but at the present day there is no explanation of finger-nails and toe-nails so far as use is concerned. If we turn to the past, however, we find the explanation at once. Our nails are all that is left to us of the things which the lower animals have and make great use of as claws and hoofs. We live by our minds, not by things like claws; and as we have not sufficient use for them, they have grown smaller and weaker in us—just as our teeth also have done, and our bones and muscles in large degree—until we have nothing left but nails.

Yet there is no doubt that they are really the same as the claws the cat uses for fighting and for climbing with, and for tearing its food; and the hoofs which the horse uses for walking upon. The ancestors of the horse had five fingers and toes, as we have, and a nail, or hoof, at the end of each; but all these except the middle ones have shrunk in the modern horse, until we find only one that reaches the ground, and the remains of another on each side. Occasionally we find a young horse born with three or even four toes. The horse's hoofs, then, are really the nails of its middle fingers and middle toes, and are very useful to it. They are made of the same material as our nails, and can be cut without pain, as our nails can.

Why some people are dark and some fair

The differences of color between various people are a good instance of those many differences which are due not to anything that happens to us in the course of our lives, but to something that is inborn in us, and usually derived from our parents. The children of two dark parents are dark, those of parents who are both brown-eyed are always brown-eyed, and so on. This way in which people resemble their parents is one of the most important things in the world, and the special name for it is heredity. We say that the thing in question, such as skin-color or eye-color, is hereditary.

All human beings may be divided into races by their color—the fair-skinned, the yellow-skinned, and the dark-skinned, and they are each apt to think the others ugly, especially when these are accompanied by other differences. In America there is a great mixture of races, though nearly all belong to the fair-skinned family of mankind. Among us are a fairer and a darker race, and it is known that at present, owing to some reason we do not understand, the darker people are increasing and the fairer people becoming fewer. It is probable that ages ago differences in color depended partly on the amount of sun, darker people having coloring matter in skin and eyes which protects them from strong sunlight; but this is a question about which we do not know much yet.

WHY ONLY TWO SETS OF TEETH GROW

When we are born we have, hidden in our gums, all our first teeth. These twenty teeth are already completely formed in all their parts at birth, and only have to get through the gums in order to be seen. A baby gets its food by sucking and not by biting, and so it is better that its teeth should be out of the way at first, below the gums. Still deeper in the gums, below each of the primary teeth, and also farther back in the jaw than the primary teeth extend, there are little groups of cells, called tooth-germs, which will some day make the second set of teeth, usually called the permanent teeth, though they are often not as permanent as they might be. There are thirty-two sets of these little cells; and though none of them are teeth, or look in the least like teeth, they have in them the power of making teeth of the various kinds that we possess.

We should take very great care of the first teeth of children, brushing them, and having them filled if they decay, even though we know that they will fall out soon; because if they are neglected the tooth-germs underneath them are very apt to be injured, and when the new teeth come they will be irregular, or have thin, soft, crumbly outsides, which easily break away or decay. Now we see why a second tooth grows when the first falls out or is pulled out. But no third tooth will grow when a second tooth has been lost, because there is no other tooth-germ lying below the second tooth, as there is below the first tooth. Thus a third tooth cannot grow.

WHY ONIONS MAKE OUR EYES WATER

Our eyes are really watering all the time, or, rather, we are producing tears that pass over the eyeball and keep it clean. That is why we wink —to carry the tears that appear under the upper lid over the surface of the eye. These tears escape into the nose, as we know. We say that our eyes water when the tears form so quickly that they cannot escape quickly enough, because then we see them water. Onions give off something to the air which excites the ends of the nerves of smell in the nose, and also excites the ends of the nerves of touch in the eyeball and eyelids, and so sends a message to the brain, telling the tear-glands to make tears quickly, and then we say that our eyes water. There is use in this, for the rapid flow of tears helps to protect the eyelids and the eyeball from the irritant the onions give off. In people who, for some reason, cannot produce tears, such things as onions will make the eyes smart severely, because such people cannot protect themselves by making their eyes water.

WHY WE ARE RIGHT-HANDED

Some people think that babies are born with a natural tendency to use one hand more than the other, and that in the greater number of cases this is the right hand; but in a few—perhaps about six in a hundred—it is the left. They say it is not worth while to train both hands equally for everything—for instance, for writing

—as this would take too much time; and we could not become so skilful with either hand if we were taught to use both equally for everything.

But others think that the inclination shown by a child to use one hand or the other is determined by the way it is held to the breast by the mother when young. Some educators even favor teaching children to write and draw indiscriminately with both hands. This is called being ambidextrous. It is certain that there is very little in the old prejudice against the use of the left hand, for left-handed people as a rule write as well as others, despite the fact that our system of penmanship was framed for right-handed people.

WHY WE SHIVER WHEN WE ARE VERY COLD

There are more good reasons than one why we shiver when we are cold. The machinery of it, as we may say, is that cold, at first, rather excites and disturbs the nervous system, just as heat usually soothes it. We notice these contrary effects of heat and cold in the case of a warm bath and a cold dip. This does not say that shivering is at all the same thing as the feeling of activity we have after a cold plunge; but in each case the cold has been what is called a stimulant. But now we have to ask whether the shivering is of any use to us, or whether it is a wholly useless and purposeless thing; beyond any doubt it is possible to show that shivering serves the purposes of the body just as hunger does, and just as even fever often does, though we think of these as things rather bad in themselves. One good reason for shivering is that it makes us aware of cold as we might not otherwise be, and so we can protect ourselves. After the first stage of its action great cold sends the brain to sleep. Shivering perhaps serves to keep the brain awake and make it aware that something must be done.

HOW SHIVERING FROM COLD HELPS TO MAKE US WARM

A very good reason for shivering perhaps can be found. Whenever a muscle works, heat is produced; indeed, a very great part of the heat of the body is made in the muscles, which have been called "the fireplaces of the body." Shivering consists of small, quick, to-and-fro movements, sometimes almost quite regular, as when our "teeth chatter," of most or all of the muscles of the body. Now, though shivering often makes us aware that we are cold, yet it helps to keep us warm, for all these little muscular movements are producing heat. So we may say that when a person, by keeping still, refuses to work his muscles so as to keep warm, the brain takes the matter into its own hands and does what little it can by setting the muscles shivering.

WHY EVERYTHING SPINS ROUND WHEN WE ARE DIZZY

When anyone feels dizzy, and perhaps almost about to faint, his brain cannot properly control the working of his eyes. They may move round from side to side, perhaps independently instead of together, and so it may look as if things were spinning round. Another reason for dizziness has to do with a wonderful part of the body near the ear, and without which none of us could sit upright, much less stand, though few people have ever heard of it. This organ, which used to be thought to have something to do with hearing, really controls our balance. In some people it suffers from a disease, and these people constantly suffer from dizziness and a feeling that everything is spinning round and round.

As every one knows, we can make ourselves dizzy, and can think that everything is spinning round, by turning round ourselves several times in one direction. This disturbs the organ of balancing, and this disturbance gives us the feeling. If you turn round the other way you put things right, by restoring the original state of affairs within the balancing organ. The name for the feeling that things are spinning round is vertigo; and vert simply means turn, as in such words as convert, invert, and others.

Sleeping with the bed-clothes over the face

Mothers sometimes get anxious about this, for they think—and quite rightly, too—that a child, or anyone else, should have its nose free when it is asleep, and not covered with the bed-clothes. But if they will watch a sleeping child, they will see that though often the child starts to go to sleep by covering its face up, yet always, when it is asleep or nearly asleep, the child's body will do the rest for itself, and the head will be moved until the nose gets free of the clothes, so that fresh air can get to it. So people who look after children really need not worry if children like to start the night with the bed-clothes almost over their faces. The child's brain, as soon as the child's self is asleep and cannot interfere with it in any way, will put things right.

What are freckles

What we usually speak of as freckles are spots of a yellowish-brown color which are seen on the skin of some people, especially after they have been exposed to strong sunshine for some time. They occur chiefly on the face, on the neck, and on the hands, because those are the parts of the skin unprotected by clothes. Some people are much more liable than others to have this coloring produced, and in some it disappears quite quickly, while in others it lasts a long time.

In all these cases the freckles are the result of the action of the sun on certain cells of the skin, which causes these cells to produce coloring matter, or pigment, which remains there for a certain time. There are cases, however, in which freckles do not appear to be caused by very hot sunshine or exposure, but which come naturally, just as the color of the skin itself is either fair or dark, according to the tendency inherited by the individual.

What makes a dimple

In order to understand a dimple, we should know the structure of the skin and what lies beneath it. In most parts of the body the skin, with its outer horny layer, and the inner living layer, which carries nerves and blood-vessels and makes the horny layer afresh from day to day, lies very loosely upon the layer of tissue beneath it. This is a loose layer, containing a certain number of fibers running in all directions, with fat-cells lying between them in healthy people—except under the skin of the eyelids, where fat is never found even in the fattest people. A few of these fibers are attached to the under surface of the skin, so that, though we can move the skin about very freely over what lies beneath it, there is, nevertheless, a limit to this movement.

But where there are dimples, as on the face, and often round such joints as the knee and the elbow, the number of fibers attached to the under surface of the skin is much increased, and they are rather short, so that the skin is depressed, or dimpled, at these points. We see what is really the same thing produced accidentally in the case of scars, which are often a little depressed below the general level of the skin because they are tacked down in the same way. But a scar differs from a dimple, as the skin over a scar has been lost, and is replaced by a new thing called scar-tissue, while the skin over a dimple is true and healthy skin.

Why damp air often makes us ill

Damp air is often cold air, and the cold has usually been blamed for making us ill, though many facts prove that it is not blameworthy at all. There is one great difference between damp air and dry air, which accounts for the fact that people usually feel at their best in dry air, while many feel at their worst in damp air.

Water is always leaving our bodies by many channels, such as the skin and the breath. When the air is dry, this journey of water is readily made, but when the air is damp, it already contains a quantity of water, and so does not easily take up more, and the passage of water from our bodies is, to a certain extent, checked.

All life, as we know, is lived in water, and if life is to go on, enough fresh water must always be supplied to the living body, whether it be a man or an animal or a plant. When the passage of water is slow, as it is in damp air, then the processes of our lives are checked, and our bodies are apt to get choked up with things which would otherwise have been burned up and got rid of. This seems to be the real key to the effect of damp air upon rheumatism.

WONDERS OF ANIMALS AND PLANTS

What the birds sing about

WHENEVER a child or a bird or anyone else sings naturally, it sings about its feelings. If you have no feelings you ought not to sing. Sometimes we sing just to show that we are brighter than other people, and when we do that we do not feel what we are singing, and everyone is glad when we stop. But the birds sing only when they must—when their feelings find their way out somehow. Then they try to tell the world how happy they are. The feelings that birds sing about are always happy feelings. When a bird is ill, or miserable, or unhappy, it never sings. Generally birds sing to express their feelings of love, and to call to their mates and their friends when they want company. At other times they sing simply for the joy of living, as the lark sings when he goes up into the sky. He sings for the joy of his nest on the ground, and for the joy of the light, and the joy of the air, and the joy of freedom. Perhaps the singing of the birds was the first music that was heard on the earth. But do remember the most beautiful thing about the birds' singing, which is, that they never sing that people may say "What a beautiful voice you have!" but always because they have some beautiful feeling which makes them sing.

Why birds fly so high

If you stand on the top of a high building on a sunny day, you can see nearly over the city. The higher you go the more you can see, if your eyes are strong enough. These birds have very strong sight. Their eyes can see as well as ours would if we used a telescope.

The big birds look down from the great height at which they are flying, and they see many birds flying below. These birds below watch the earth. They see food thrown away by men and placed in the garden by children, and in a moment they fly down to get it. The bird which is right up in the air knows what they are doing, and swoops down quickly to take its share. These birds get a good meal. If they did not eat that food it would soon become bad in the sunshine, and make us ill; but it serves the birds for a good dinner, and by eating it the birds save us from being ill. So we see how in all parts of the world Nature looks after her big family.

THE USE OF A MOTH

Hair and wool are rubbed off the thousands and thousands of hairy and woolly animals in the world, and, if this hair and wool were never destroyed, it would, in the course of many years, become a great nuisance. The moths eat this and so prevent us from suffering from such a nuisance.

But moths eat our clothes, you say.

Moths never eat the clothes which we have on, or the clothes which we wear regularly. If you have too many clothes to wear, you should give them to poor people who have not enough. So that moths teach us not to be greedy, not to hoard up things which other people would be thankful to have!

That is a lesson which not all of us would expect. Other unpleasant things teach us just as well. Those of us who have relatives in hot lands know how badly people there suffer from fever.

WHERE THE FLOWERS GO IN WINTER

The flowers of most plants can live and be useful for only part of one year, when there is plenty of light and warmth. When the summer goes they die. You know how the roses on a rose-bush die, but you know also that the rose-bush itself does not die.

In just the same way the leaves of most trees die at the end of the summer, but the trees go on living. When the flowers and the leaves die and fall, their death and fall is really a sign of life in the plant, or bush, or tree that bears them. If the whole bough of a tree is killed by something in the summer, the leaves will remain on it when the leaves of all the living boughs have fallen. There is really no waste or loss to a plant or a tree when its leaves and flowers die.

Before a leaf falls it changes its color, as we know, because the plant or tree is taking out of the leaf all the useful things that it needs for its own life. Then, at the base of the leaf, it forms a thin layer of something rather like cork, so that, after some of the useful things have been taken out of it, the leaf is left to die. There are still some useful things in the leaf, however, only they need something to be done to them before the plant can use them.

WHAT HAPPENS WHEN A LEAF FALLS

Many changes take place in the leaf as the summer goes away. When the leaf falls to the ground, there are waiting for it many tiny living creatures called microbes, which, as we say, make it decay. But this really means that the substance of the leaf is changed in such a way that it can be taken up by the plant from the soil and built up again into the plant when the spring comes. This is one of the most beautiful and wonderful things in Nature, and there is no greater lesson we can learn than that what looks like useless death and decay and waste is really nothing of the sort, but a living process that makes for more life.

You will say, Why should not the leaves and flowers live on all the year round, as they do in some plants for special reasons? But the leaf is made in order to use the sunlight, and in the winter there is not enough sunlight, and so the leaf would be wasting its time.

So the plant takes what it can use from the leaf and the rest of the leaf is changed, so that the plant can use that, too, when the summer is coming, and there is use for new leaves.

HOW THE MOSQUITO CAUSES FEVER

And now, after all these years, after many brave men have died from fever, a doctor has discovered that fever there can be checked, and can be done away with. The fever is caused by the sting of a little insect called a mosquito. What we call the "midge" in this country is really one form of mosquito. In the hot lands this mosquito, when it stings, forces a deadly poison into the blood of the person it bites.

What the doctor does, having found out the cause of the fever, is to get rid of that cause. He finds that the mosquito lays the eggs from which the young ones are born in moist, swampy places. So the stamps are drained and the puddles dried up. Then the mosquito eggs cannot be hatched, and, there being no mosquitoes, men cannot be poisoned. The mosquito has taught men that they must be clean and careful in their homes.

How a spider spins its web

Great men say that nothing is more wonderful than the cleverness of the spider. The silk of which it makes its web comes from its body through tiny tubes, like the finest hairs. Many of them come out at the same time, but after leaving the spider's body they are all formed into one rope of silk, which is so thin that a hundred of them together are only as thick as a hair. The end of the silk is fastened to a twig or a leaf or a piece of wood Sometimes the spider makes the fastening itself, or it may let the silk float from its body for the wind to blow it about until it touches something and clings there.

When both ends have been made fast, the spider is able to run down the thread and fix several more threads, perhaps twenty, all fastened to different points, but meeting in the middle. These are the cross ropes of the web. Then other lines have to be woven round and round these, making perhaps twenty rings. All this beautiful silk has come from the spider's body. The spider works hard and fast, and when the web is begun the work is finished in less than an hour. The web is then so strong that the wind cannot blow it away and the rain cannot break it.

The purpose of the spider's web is to catch insects, so the spider has still much work to do. Insects would not be caught in a web if they could walk or fly out of it, and to prevent their escape the spider covers all the web with a glue-like substance, which sticks to anything entering the web and holds it fast. We cannot see this glue with our eyes, but there are thousands of tiny beads of it dotted all over the spider's web.

HOW NATURE HANGS HER BEADS UPON A SPIDER'S WEB

This is a spider's web covered with dewdrops. The spider makes its web with silk from its own body, which it spins into rings and threads until the web is complete. A web is so strong that wind and rain do not break it. There is nothing prettier than the spider's web with the hanging dew upon it.

How the birds find their way

We know that many birds fly away home over the sea to warmer countries when our summer ends, and return when it begins again. This flight across the seas is called migration, and is one of the wonders of the world. We say that instinct guides them; but this does not tell us how instinct is able to do so marvelous a thing. When we cross the seas we are guided by those who have been that way before. We have charts and pilots and compasses, and even then we sometimes make mistakes.

But the birds have none of these things. They do not even take provisions with them; and we know that some of them become exhausted with their long flight, unsupported by food, while not a few are nearly dead. Yet, though this is so, the wonder of their flight, and their guidance, remains.

We can only guess that perhaps the older birds teach the younger ones, as happens with ourselves; and if anyone finds it hard to believe how they can remember, all we can say is that birds have wonderful memories for these things. The birds also have a wonderful sense of direction.

We know that some people can never find their way. They turn to the left when they should turn to the right, and so on. Other people scarcely ever make a mistake, even though they have been only once in a place before.

Probably birds and many other animals are even wiser than the wisest human beings in this respect. Perhaps if you bandaged a bird and "turned it round three times"—as when you play games—it would remember just how far and often it had gone round. But when they turn you round, you don't know whether you are facing the fireplace or the window. Your brain can't remember the turnings as the bird's brain does.

What makes a bee hum

The humming of the bee and of so many other insects is not like the murmur of the seashell, which picks up sound like a telephone, but is made by the bee itself. You have never heard a bee hum when it was crawling —nor any other insect. This tells us what we might have guessed, that the bee's humming is made by the movement of its wings when it flies. The noise is not made by its voice-box, as when you sing, for the bee has no voice-box. But its wings move very quickly —a bird would "hum" when flying if its wings moved quickly enough—and as they move to and fro, or vibrate, or tremble, they set the air moving, and you know that waves in the air make sound when we hear them.

If the waves are too slow, as when you wave a stick in the air, or when a bird flaps its wings, we hear nothing. If they are too fast, as they are in the case of some insects, perhaps, and in other cases, like the scream of the bat we cannot hear them; or, to take the bat, some people can hear them, but many cannot. Thus there are many sounds we cannot hear, as there are many colors we cannot see. But the vibrations in the air made by the bee's wings are of a rate that is within the range of our hearing—if the bee is near enough—and so we hear a humming. No doubt you will guess that that word, like "murmur," is made to imitate the sound of which it is the name.

Did tame flowers once grow wild?

Certainly all flowers did once grow wild, and all animals, too. There are certain kinds of flowers and animals which men have, so to speak, made by choosing the kind of thing they wanted and leaving the rest, and so gradually getting such things as the garden rose, the pouter pigeon, and so on. These are what we call cultivated varieties, but all of them, even the most curious and newest orchid, or pigeon, or breed of dog, have been made from wild or natural forms; and, of course, before man started doing this, all flowers, all plants, all animals, were wild. Even now, if we are careless, our garden plants will return sometimes more or less completely to their natural state, and so will domestic animals. On the other hand, cultivated flowers may escape from a garden, as we say, their seeds being carried by insects or the wind, and may then appear to have grown wild. There is no end to what we may do by cultivating plants and flowers. Men used to try only to make beautiful forms, but lately they have tried to make useful ones, and have succeeded, especially in making from old kinds of corn new kinds which are far more valuable for human food.

Does a worm breathe under ground?

Every living thing breathes, whether in earth, or on the earth, or in the sky, or in water. If it cannot get air it dies. The worm really has no trouble at all, for there is plenty of air and to spare in the earth anywhere near the surface. Of course, if you dig deeply into the earth, there will not be enough air for a thing like a worm, which needs a good deal; and you will find only living creatures, like some microbes, or tiny plants, which need very little air. Further down still you will find no living things at all. There is no life at all in the inside of the earth.

Do seeds breathe?

Seeds are no exception to the rule that every living thing must breathe. The seed gets its air, or, rather, its oxygen from the air, just as the worm does. So you must not plant the seed too deeply, or it will not get enough air, and then it will die. You may wonder that a seed should breathe, but that is because we always think of breathing as if the only kind of it were our breathing, with ribs and lungs.

The air in the earth, which enables plants to grow from seeds and trees from acorns, and keeps alive worms and insects and many microbes, is known as ground-air, and as its warmth depends on the warmth of the earth, it is very different at different times of the year. That is one reason why certain illnesses attack us at certain times of the year—because the warmth of the ground-air is just right for the growth of the microbes that cause those illnesses. Remember, there is air in the earth as there is in water.

Where the snail finds its shell

The snail makes its shell from its own skin. The same is true of the shell of the oyster, or that of the lobster. Our own skins, we know, can make things which are fairly hard, such as our nails; and it is also true that the hardest things in our bodies, our teeth, which are, or should be, even harder than the shell of the snail, are really made from our skin, which has been, so to speak, turned into our mouths so as to line them. There are really few things more wonderful than the way in which soft, living creatures, mostly made of water, are able to make the hardest things, like teeth and wood and shells and pearl, and so on. If we look very carefully at the skin of creatures like the snail, we can see how its outside cells are specially made so that they can gradually get harder and harder, until they cannot be called skin at all, but are really nothing else than shell. We can watch very much the same thing if we look at the cells at the base of our nails or the cells that make the horns of animals, and see how the soft skin is gradually changed.

How flies walk on the ceiling

The reason, no doubt, is that the fly's feet, besides being just the least little bit sticky, are made like suckers, and hold on to whatever the fly walks upon. Then, of course, we have to remember that the fly's body itself is very lightly made, just as a bird's body is, because both are meant to fly; and this makes it easier for a very little force to prevent the fly from falling even when it is upside down.

Why spiders do not get caught in their own web

It is the strength of the spider that prevents him from getting caught in his web, which is only made for catching creatures much weaker than himself. We know for certain that the spider can cut his web when he pleases, so that there is no fear of his getting caught in it. The spider is a wonderfully clever animal, but he is not brave. If an insect that is too big for his taste comes against his web, he will sit quite still in one corner and never move until it goes away, and sometimes he is so frightened that he simply cuts his web rather than get into difficulties with something that is more likely to eat him than the other way about. In this he is cleverer than some men, who make nets to catch other people and get caught in them themselves. In proportion to his size, the spider is a very strong animal, and it is really wonderful that he can cut his own web, for they say that in proportion to its weight it is one of the strongest things known.

How birds know how to build their nests

It is by the power of what we call instinct. We human beings do very little by instinct; we have to learn for ourselves almost everything that we do. We cannot write or read instinctively, and if we are to learn well we must practice, and we must have help from older people to teach us. Only we have this advantage, that there is no limit to what we can learn.

The instinct of animals, however, shown in the spider's web or the bird's nest, or a thousand other things, is quite different. There is no learning at all. Many animals have to do a most difficult thing only once in their whole lives, and after doing it they die; and we know for certain that they have never seen any other animal do it. They have never learned, they have never practiced, and yet they do it perfeclty. That is the power of instinct; but the weakness of it is that it can do only what it is made to do, and it is for this reason that intelligence is so vastly superior to the best instinct.

Why fishes cannot live on land

Every living thing must have air or die. The fish comes out of the water, where there is very little air, into the air itself, and there it dies for lack of air. It is drowned on land for lack of air, and dies of what is called suffocation, just as you or I would be drowned in the water.

But why cannot the fish help itself to the air around it when it is put on earth? Why should it starve in the midst of plenty, like a rich man who has something the matter physically? The reason is, that in order to breathe air you must have lungs, or something like lungs, and the fish has none; while in order to get the air which is dissolved in water, which the fish does, you must have something quite different from lungs, which are called gills. The fish has no lungs, but only gills. We have no gills, but only lungs. Therefore, we die in the water and the fish dies out of it. If an animal had both gills and lungs, then it would be able to get air from the air or to get the air which is in water, as it pleased; and it could live both on the land and in the sea.

How we can tell the age of a tree

In the case of some trees you can only guess at this, but in the case of many you can tell exactly, because the tree makes a fresh growth every year under the bark, and as this differs rather in the earlier part of the year from the kind of wood which is made later, you can easily distinguish between one year's growth and the next. So when the tree is cut across—but that, of course, means killing it—you find that it shows a number of rings, one inside the other, and each of these rings corresponds to a year of the tree's life.

In the case of a man or a woman, the number of years he or she has lived need not make any difference or leave any mark. Some people are far younger at eighty than other people at thirty, for we do not live by the changing seasons of the year. But all plants do this in some degree or other, and thus they show the marks of their age. Another way in which trees differ from us is that, as long as they are alive, they go on growing, while we, of course, are quite different, and after the earlier part of our lives is past we never grow any more. Some trees live to be many hundreds of years old. even 1000 years or more.

Why the bark grows on a tree

If the bark did not grow on the tree, the tree would not grow. The bark is a necessary part of the tree, and if you strip the bark off you will kill the tree. In the first place, the bark does one or two things which are useful but not very important. The outside of it is usually pretty tough, and has become more or less dead so that things do not hurt it, and it protects the living part of the tree inside. Often many animals and plants live on the outside of trees without doing them any harm, but that is really a very small thing. The inside of the bark is the most living part of the tree, we may say; not only so, but it actually makes the tree. All the growth of the tree in thickness is due to the making of the wood, and it is the bark, the soft living part of the inside of the bark, that has made all the hardest wood of the biggest and hardest tree-trunk. Also, there are channels in the bark through which the sap of the tree, its food and water, run, in much the same way as the blood runs in our own blood-vessels.

What makes a cat purr

The noise a cat makes when it purrs is really a kind of talking, for it tells you that the cat has a certain feeling. It feels pleased and happy, and it says so in its own way, and no doubt another cat would know and understand what it felt, and very likely would feel pleased and begin to purr too, just as the company of happy people usually makes us happy. When a cat purrs, if you put your hand on it you can feel its whole body trembling. But when anyone speaks or sings—especially if he be a man with a voice low in pitch—if you put your hand on his chest you can feel him vibrate, or tremble, just like the cat. In the case of the man, we know that it is his vocal cords in his throat which he has set trembling, and they have set the whole of his chest vibrating. Whether anyone is sure what it is that the cat purrs with is doubtful, but the cat has vocal cords just as we have, and we may be sure it uses them.

How a dog knows a stranger

A dog has wonderfully good eyes, but it has a still more wonderful sense of smell. Our own sense of smell is so very feeble and unimportant that only after we have made a long study of animals can we realize how useful and delicate this sense may be. Thus a dog "knows a stranger" chiefly because the stranger has a strange scent. If the stranger wore the clothes of the dog's master, then the dog would take him for his master, even though the stranger looked very different. After a time, very likely the dog might begin to feel uncomfortable, and act as if he thought something was wrong somewhere.

But, you see, every creature forms its judgments mainly by means of the particular sense which is best developed in it, and which it has therefore learned to trust best. We know people by our eyes, and though sometimes a man's voice may be exactly like the voice of a friend, yet we do not think that it is our friend if our eyes do not tell us so. Just in the same way the dog trusts his nose rather than his eyes, because his sense of smell is his best sense. Lastly, do not forget that it is because the dog has the wonderful thing called memory that he "knows a stranger." It is as if he said to himself, "This is not a smell I remember"—that is to say, it is a strange smell.

Why the Leaves Change Color

In the autumn the beautiful green color made by the sunlight in the plant changes and goes. It is not that the plant is dying, but that it is going to rest for the winter, when the air is cold and the days are short. After all, many animals go to sleep all the winter, and for the same reason. Hibernus is the Latin word that has to do with winter, and so we say that some animals hibernate. Well, we might just as well say that many trees hibernate, and since they are not going to use their leaves, they take out of them everything that will be useful. In doing this the tree changes the green in the leaf, and so we get various colors produced in the autumn.

Why Certain Seeds Come Up at Certain Times

Young creatures come up, if they are plants, or are born, if they are animals, usually at the time of year which is best suited for their particular way of life. That is the general rule throughout the whole world, both of plants and of animals; and the case of the seeds which come up in spring, some sooner and some later, according to the way they are made, is really only the same thing. One exception to it is ourselves. All the year round, babies are born—Christmas Day and Midsummer's Day alike. The reason for this is that it does not matter what time of the year it is when a baby is born, because it depends, unlike a plant, not upon the weather and the particular amount of sun that is shining or the particular amount of warmth in the earth, but upon the love of its mother, and that it is the same all the year round. While, like all other living creatures, we depend partly upon the sun, and so on, yet, more than all other things, we depend upon the care of those who love us.

Why Animals in Snowy Countries Wear White Coats

The use of the white coat is to protect the animal from its enemies by making it difficult to see. If the animal keeps still it can scarcely be seen at all when its coat is the same color as the snow. But if it had a white coat in summer, when the snow goes, it would be easily seen, and so often its coat changes in summer, and the fur takes other tints, more like the color of the ground and the plants among which it lives. This is called protective coloring, and is very useful to many animals. But sometimes it happens that an animal which lives by catching others is also white in winter snow, so that it can get near its prey without being seen. Some insects do the same thing, and when they sit quietly among the leaves of certain plants no one can tell which is insect and which is leaf, so the birds cannot find them.

What brings life out of dry seeds

We may be sure that the life is there, or it would not come out of the seeds. The seeds are the children of plants that were alive before them, and part of their parents' life is in them. But it is quite true that a dried seed is very different from one which is sprouting, and it is fair to say that its life is resting or passive or suspended for the time. It is alive, we know very well, for it can be killed by boiling it or by a poison or in many other ways, and a dried seed may be dead or alive, as an egg may be dead or alive.

You will never be able to get a chicken out of a dead egg, or a plant out of a dead seed, but you will get a dried seed—provided it has not been killed—to sprout if you add water to it. It is because it is dried that it seems to stop living, which is not the same thing as to die. We know that it is not the same thing, for when it gets water it shows us that it is not dead. The chemical changes which are necessary for all active life must have water, if they are to go on. The water does not make the life come out of the dried seed, but reveals it. If you have injected a drop of poison into the seed first, then the water will fail to make it sprout, for it is killed.

Why some plants are always green

Though it is the common rule that green plants lose their leaves in the winter, when there is less sun for them to use, yet we must remember that the variety of life is infinite, and that one plant has one way of living which suits it, and another has another. Thus, some plants, which we call evergreen, develop a strong kind of leaf which lasts all through the winter, in spite of the wind and the wet, and uses the winter sun whenever it shines. Probably we shall find, at any rate in some of these cases, that the plant really belongs to a part of the world where there is plenty of sun in the winter, so that it is quite worth the plant's while to keep its green leaves all the year round. We must not think that evergreen plants are necessarily stronger or better than those whose leaves fall in the winter, for we know that the change and the fall of the leaf is not really a process of decay or of death, but a living process, meant to serve the life of the plant.

Why birds eggs are of different colors

We know, of course, that the differences in color depend upon the presence in the various shells of various coloring substances or pigments, and it is interesting to see how a particular kind of bird always produces the same kind of color in its eggs, just as it produces a particular kind of color in its own feathers. The particular kind of food the birds feed on, nor yet the particular surroundings it lives in, have likely much to do with the special color of its eggs. This must really depend upon the particular chemistry of the body of the bird. I do not mean that you cannot change the color of hens' eggs, for instance, by food, but you will never get a hen to lay a speckled green egg. The color of the shell is really as special to the particular bird as any of the things by which we know one bird from another.

Use of the different colors of birds' eggs

If we compare the colorings and markings of a great number of birds' eggs with the places in which they are found, we discover that in a large number of cases the eggs are so like their surroundings that they are difficult to see at all unless we look quite closely. For instance, a ringed plover's egg has the same general coloring as the sand on which it lies, and it is spotted over with black dots which look like tiny shadows. This makes it difficult to see the egg at all. In other cases the blotches or markings on the eggs look like an irregular piece of dark material lying, perhaps, on the beach. Thus, the eggs of the tern or gull sometimes look like stones or spotted pebbles, and, on the other hand, the stones themselves look so like eggs as to be easily mistaken for them at a slight distance; so that the reason for the coloring of eggs is no doubt to help them to be hidden from sight.

Why a bad egg floats and a good egg sinks

A fresh eggs consists of a mass of yolk, together with what we call the white of the egg, and this, being heavier than water, will cause the egg to sink when it is placed in water. But in an egg which has become addled or rotten, the yolk and white have split up into other things, and produce gases which cause the egg to be much lighter than it was before. In fact, such an egg does not weigh as much as an equal bulk of water does, so that if placed in water it will float and not sink.

Can a fish hear?

Although fishes are like some other animals in having no visible signs of ears, yet they have ears which conduct sound to the brain. Their organ of hearing consists simply of an internal ear placed inside a gristly capsule. In some fishes—as, for instance, the dog-fish—there is a fold known as the false gill, which is no doubt the remains of a real gill, but is now used for transmitting sounds to the internal ear. In the wall of the capsule which contains the internal ear there is a thin spot, and it is through this thin part, corresponding with what we call the drum of our own ear, that the sound is conducted. Thus, we see that in the case of some of the fishes there has been a change of function of an organ which was in the first place a gill, but has now become part of the hearing apparatus. In other words, it is a structure at one time used for breathing, but now used for hearing.

Why fishes do not drown

All animals and plants must get air in some way or other in order to live; or, to be more strictly accurate, they must have a supply of oxygen, which is one of the gases in the air. Should this supply of oxygen fail, death must come, no matter whether it be from drowning or from any other cause. When a man is drowned, what really happens is that on account of his being so long under the water, his supply of life-giving oxygen has run short, and as he can only get it when he is in the air, he dies.

But this is not because there is no oxygen to be had in the water, for, as a matter of fact, there is quite a large amount of this life-giving gas dissolved in water, only human beings and animals breathing by lungs cannot make use of it. Their organs are only adapted for breathing air. The fishes, on the other hand, breathe by gills, not lungs, and the wonderful way in which gills are made enables them to extract the oxygen from the water. Being able to do this, they can live under water perfectly well. But if anything should happen to prevent the fish from getting oxygen from the water, or if something should happen to the water to deprive it of its oxygen, then the fish would be drowned, as would any other animal.

Why a moth flies round and round a candle

No one can say what it is in the brain—or beginnings of a brain—of the moth that decides it to like the light; and it is quite clear to everyone that this liking does the moth no good —at any rate, in the case of such a light as the candle. It may possibly be that it benefits the moth, and other creatures that behave like it, to fly towards light from darkness; and perhaps we should find this to be so if we knew enough of the lives of these creatures. But much study has lately shown that animals and plants can be divided into those which go naturally from darkness to light, and those which go naturally from light to darkness. Learned names have been applied to these habits—names which mean that the creature turns sunwards or away from the sun. Different plants and different parts of the same plant behave in similar ways; and if we notice the behavior of a baby towards a bright light we shall see that it is really like the moth. We find also that different creatures tend to move towards or away from other things besides light—such as heat, gravitation, electricity, and all sorts of chemicals and smells. Some grown-up people are like the moth—they move to the sunny side of the street; and others are like insects that usually live in darkness and fly towards it—they move to the shady side of the street.

Where plants get their salts

The salts of plants are necessary for their own lives, and are very valuable for us when we eat the plants, or when we eat other animals which eat the plants. There are very few salts in rain-water; but the rain-water, when it becomes what is called soil-water, melts, or dissolves, into itself everything that can be melted from the earth around it. Exactly what these salts are must depend, of course, upon the particular kind of soil, and this is very important, for some plants require some salts and some require others; so the quality of the soil in various places decides what kinds of plants can or cannot grow there. The plant gets all its water and all its salts by its roots; and it can get no salts in the solid state, but only those that are dissolved in the soil-water. If we want certain plants to grow—such as grass or wheat, or even trees—we may often supply salts to the soil, so that they may be dissolved by the soil-water, and taken into the body of the plant.

Why wood rots away

Well, there are kinds of wood that will not rot away, even though they are kept in water. The ancient city of Venice is actually built on wooden piles buried in the shallow sea; and these have lasted for many centuries already. This wood does not rot because the things that make wood rot cannot attack it, and wood does not rot without a cause.

We shall begin to guess what it is that makes wood rot when we learn what is done to wood that must be exposed to wet and yet must not rot—for instance, the wood of which railway ties are made. These are often soaked with a chemical substance called creosote; and the particular property of creosote which makes it so valuable is that it is poisonous to microbes. So the answer to the question, in one word, is microbes; and wood will not rot if it is charged with something that kills microbes, or if it is made of stuff so hard and tough that even microbes cannot digest it; or if, as in the case of Venice, it is very good wood, and also protected from the kinds of microbes that can rot wood by being kept in salt water.

The age of animals

The prize for the land animals has to be given to the tortoise. This animal lives, under favorable conditions, for between 300 and 400 years. One died in London in 1906 which was stated to be at least 350 years of age. Another reptile is the crocodile, which, given fair play in its native wilds, can live for 300 years.

It takes an elephant a long time to grow up, and it takes him a long time to wear out. Well treated, he should live to be a hundred. That is the age to which the eagle is supposed to live, but some people put down the age he may reach as 200 years. Even that is young compared with the life of the whale. This can be shown to last for 500 years.

In the following tables the extreme ages of things like the whale and eagle and tortoise are not given. The tables merely set out the ages to which certain animals often live.

THE NUMBER OF YEARS THAT BIRDS LIVE

Wren	3	Canary	24
Thrush	10	Crane	24
Robin	12	Peacock	24
Blackbird	12	Skylark	30
Hen	14	Sparrow	40
Goldfinch	15	Goose	50
Partridge	15	Pelican	50
Pheasant	15	Parrot	60
Lark	18	Heron	60
Nightingale	18	Crow	100
Pigeon	20	Swan	100
Linnet	23	Eagle	100

THE NUMBER OF YEARS OTHER ANIMALS LIVE

Rabbit	5	Horse	27
Sheep	12	Camel	40
Cat	13	Lion	40
Dog	15	Elephant	100
Goat	15	Crocodile	300
Cow	25	Tortoise	350
Pig	25	Whale	500

WHY BIRDS CAST THEIR FEATHERS

Feathers become worn, torn and broken, and must be replaced. The moulting of birds is similar to what takes place in other forms of animal life. Horses grow long coats of hair in winter which they shed in summer. Dogs cast their coats. Snakes cast their skins; crabs and other shell-fish cast their shells. If a crab lived always in one shell his body could never grow any bigger. At a certain time in the year his flesh becomes very watery, so he can draw his great claws through the narrow opening at the top of the shells in which they are enclosed, and he comes out of his shell almost as soft and pulpy as an egg in its skin with its shell removed. Birds are never left bare like this. They moult gradually. Some are so completely robbed of their strong feathers that they are glad to go into hiding until the new ones grow. They are then as defenceless as is the stag which has shed its mighty antlers.

WONDERS OF LIGHT AND SOUND

WHERE MUSIC COMES FROM

MUSIC is simply a special kind of sound. Other kinds of sounds we call noise. All kinds of sound are really the same, and they simply consist of waves in the air.

If you say you can scarcely believe this, because you have never seen them, the reply is that they are not meant to be seen but to be heard, and you have certainly heard them. These waves in air that we hear, though we cannot see them, are really wonderfully like waves in water, which we can see, though we cannot hear them. The air, after all, is not so very different from a great ocean of water. If there were two fishes living in the sea or in a lake, you can understand that if one of them flapped his tail he would make a wave of water which the other fish might feel.

When we speak or sing, or clap our hands, we make a wave of air very like that wave of water, and other people feel it in a particular kind of way, which we call hearing. After all, hearing is just feeling with our ears. These waves in the air move very quickly, and are very tiny, but they are of many different sizes, even though they are all very small. The different kinds of waves make different kinds of sounds. If you make a wave in the air which is jerky and not regular, but just comes along "anyhow," then the ear, when it feels or hears that wave, does not like it, and that is the kind of wave that makes a noise. But if someone is singing, or if you strike a note on the piano, then the wave that is made is a regular and even one, and the ear likes it, and calls this a musical sound.

How the piano plays

The simplest way of understanding this is to take a piece of string and stretch it tight at its two ends. This piece of string is just like the wire inside a piano, which you hit when you strike a note; and the wire is stretched just as the string is stretched. When the piano-tuner comes, he goes over all the wires inside the piano to see that they are stretched just as much as they ought to be. Well, if you take this string and twang it, you can see it moving backwards and forwards, and can hear a low sound. When anything moves backwards and forwards like this, we say that it is vibrating, which simply means trembling. Every time it moves it makes a little wave in the air. If you make the string shorter, or if you stretch it tighter, it vibrates more quickly, and the musical note it gives out is a higher note, more like the treble of the piano. When we speak or sing, we make two cords in our throats, called the vocal cords, vibrate, or tremble, just like this cord or string that we can see vibrate for ourselves.

Why we see ourselves in the glass

The glass is made with a layer of quicksilver behind it. If that were not there, we should see through the glass as we see through the window. But the quicksilver prevents the light from going through and sends it back again. The glass and the quicksilver are both perfectly smooth and flat.

Now, we can see ourselves in any thing that is perfectly smooth and flat, and that is able to throw the light from our faces back to us. Of course we cannot see ourselves in what we call dull surfaces, because they keep the light; nor can we see ourselves in things with rough surfaces, because they do not throw the light back fairly, but scatter it in all directions. If you throw a ball against a perfectly smooth wall, and throw it straight, it will come straight back to you. If you throw it sideways, you know that it will come off the wall in a certain way. You could easily throw it to the wall so that it would bounce off to a friend standing further along the wall.

But if instead of a smooth wall you had a heap of loose stones to bounce the ball against, you could never tell where the ball would go after you had thrown it.

Now, when you stand opposite a good glass, the light from your face hits the glass and comes straight back, just as if it were made of a lot of little balls; but if you stand opposite something that is rough, the light comes back this way, and that, and the other, just as if you threw a handful of marbles against a heap of stones—and, of course, you cannot see yourself. The glass throws your image back to you as your body throws its own image on the ground in the sunshine. But on the glass your image comes back light, and your shadow on the ground is dark, because it is made by your standing in the way of the light.

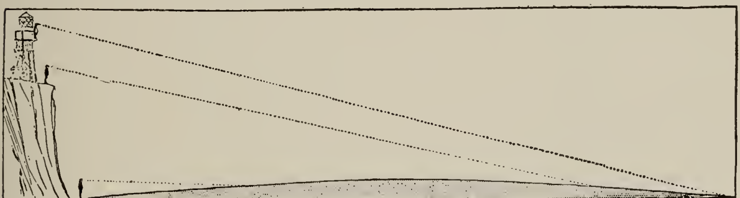
What makes the colors of the sunset

Now, when the sun is setting, its light does not come so straight down upon us as it does when the sun is high in the sky, but, in order to reach our eyes, it has to pass through a long layer of air, just as if you stick a needle straight into an orange it does not have to go far through the peel before it gets inside, but if you stick it sideways in the orange it has a long journey through the peel before it gets inside. So the light from the setting sun passes through so much air, and all the dust and smoke, and so on, that is in the air; and all these take something out of the white light, and throw out what they do not take. The things floating in the air are of all sizes, and so we get many different colors in sunset. So it comes about that sunsets are often finer when the air is not pure, but has much dust in it.

Why we see farther if we are higher up

The scientific explanation of this would be that "range of vision is determined by the altitude of the observer." In simple language, this means that the higher up we are, the farther we can see. That is because our world is a globe. Perhaps you can understand better how this is if you stand in front of a row of houses that form a bulging crescent. Stand close to one of the houses, and turn your head first to the right, and then to the left. You cannot see much of the row of houses—perhaps only a little bit of the house on each side of the one of which you stand in front. Step back into the middle of the road, and look again. Now you can see a good many more of the houses, but still not all if the row is long. Then go to the far side of the road, and a good many more will be found to have come within the range of your eyes.

To look for the horizon is much the same thing. The earth is round, and the farther we are above the ground along which we are looking, the farther we can see.



How far off is the horizon?

The word horizon is Greek, and is derived from the Greek word for a boundary, which is horos. Of course, we understand that the horizon is not really the boundary between earth and sky, but merely the boundary between them as they appear to our eyes.

This is a question often asked. As we stand by the seashore, the sky and the sea seem to meet. We can see a line which seems to be the end of the sea and the bottom of the sky. That is the horizon. Similarly, if we stand upon a plain of land we can, if there are no trees or houses in the way, see where the end of the land seems to touch the bottom rim of the dome we call the sky. That also is the horizon.

Its distance depends upon how high our eyes are from the level of the sea if we are looking across the sea, or from the level of the land across which we are looking if we are looking over a plain. The picture shows clearly how this is so. The boy standing by the seashore is looking out upon the sea from a distance about four feet higher than the level of the sea—the height of his eyes from sea-level. He can see just a little more than two and one-half miles in front of him, and his horizon is just this distance away. The eyes of the boy on the edge of the cliff, on the other hand, are 100 feet above sea-level, and he can see about 13¼ miles off, and that is where the horizon is. Again, the top of the lighthouse is 150 feet above sea-level, and if a boy looked out on the sea from this point, he would see about 16¼ miles, and his horizon would be the same distance.

WHY WE CANNOT JUMP OFF OUR SHADOWS

Wherever we go, our shadows will follow, of course. We all know what makes shadows, but we do not all know what wonderful things shadows make. For instance, the moon is lighted by the sun's light; and sometimes the earth "gets in the light," as you do when you stand in front of the lamp by which someone is reading. So the earth prevents the sunlight from reaching the moon, and throws a round shadow, which we can see across the moon as the earth gets in the way. This is an "eclipse of the moon."

Then shadows make strange things when they are thrown far away. The shadow of your hand becomes very big if it is thrown on a wall far off. And sometimes the shadow of a man's body may look like a strange giant and frighten the man who is making it! There is a mountain in Germany, called the Brocken, nearly a mile high, where a man's shadow is sometimes thrown on the clouds.

WHY THE SKY IS BLUE

This was found out last century by John Tyndall. You would never guess the reason. The sky gets its light from the sun. When the sun is away, the sky is dark. Therefore, the blue of the sky must be somehow thrown to our eyes from something in the sky which keeps all the other colors in the white light of the sun, and throws back the blue, and that is what happens.

The sky is filled with countless tiny specks of what we may call dust. These are of just such a size that they catch the bigger waves of light, which make the other colors, but throw to our eyes the shorter waves of light, which make blue. If you could do away with all the solid stuff in the air, the sky would be dark, and all the light of the daytime would come directly from the sun. Skylight is reflected sunlight, but only the blue part of it.

WHY IT IS DARK AT NIGHT

If you take a ball and hold it near a bright light the half of the ball next to the light is shone upon, and the half of the ball away from the light is dark. If you mark a spot on the ball, and then turn the ball round and round like a top, that spot will be shone upon half the time and will be in the dark the other half of the time. We live on a big ball called the earth, which is always spinning round and round, and it is shone upon all the time, day and night, by a bright light called the sun.

The place where we live is like the spot on the ball, and as the great earth-ball spins, part of the time we are on the side next to the sun and part of the time we are on the side away from the sun. When we are on that side it is dark at night, but while it is our night it is daytime for the people who live on the other side of the ball. However dark it is where we live, the sun is always shining somewhere, and the earth is always traveling towards it or away from it. The sun does not come to the earth, but the earth comes into the sunlight. If you think of the ball and the light you will understand that, however dark it is, the earth will soon carry us round into the light again. Have you ever heard one of the most beautiful lines in all poetry: "There is a budding morrow in midnight," meaning that every night a day is being born.

THE NOISE LIKE WAVES IN A SEA SHELL

This pretty idea is only just a poets' fancy, and nothing more. The truth is, we only imagine a likeness between the sound of the shell and the sound of the sea; though I quite admit that it is easy to imagine, and that we may forgive the poet who said that the shell is "Murmurous still of its nativity"—its place of birth. Murmur is a good word for this, made on purpose to imitate the sound.

Really, then, the shell is one of those things which can pick up and make stronger certain kinds of sounds. The wooden part of a violin does this: if you take it away and play on the strings without it they make a feeble, thin, unpleasant tone. These things that make sound resound are called resonators. The body of the violin is one, a sounding-board is another, and a shell is a third.

THE SOUNDS WHICH THE SHELL PICKS UP

"The shell," you may say, "makes a murmur even when everything is quiet; surely the sound is made within itself—it murmurs still the sounds of its birthplace." The answer is that really it is never quite quiet, and that the shell picks up sound so slight that we do not hear them at all without the shell. This has been shown in a new way. A sound-proof room was built. People inside it heard their own hearts beating, and so on. But there were cut out of the room all the tiny noises that usually go on, and when a shell was held to the ear nothing at all could be heard. The shell is only a telephone, and if no sounds come for it to resound, it is silent. But the beauty of the poet's idea remains; and it is true as a picture of what happens with men and women, and their remembrance of the places and people of their childhood.

WHY A NOISE BREAKS A WINDOW

Noise is an irregular wave in the air—which is a real thing, and has weight and power, remember. A wave of air may break a window exactly as the wave in the sea will break a breakwater, though, as the name tells us, the breakwater will break the wave, as long as that wave is not too strong.

If you think a moment, you will see that every time a noise gets through a shut window it shakes the window. If the noise is coming in from the street, the air outside is thrown into waves which pass through it until they strike the window, and shake it; then the window shakes the air inside the room in exactly the same way as the air outside shook it, only perhaps not quite so strongly. And so the noise reaches you, just as if you had heard it outside, only not quite so loud. Well, plainly, the noise has only to be loud enough—that is to say, the waves in the air have only to be big enough—to shake the window more than it can stand, and then it breaks. Now, since air is a real thing which has weight and power, the truth is that a noise breaks a window just as does a baseball.

WHY THE KETTLE SINGS

Everything that sings, sings really for the same reason, because it is set vibrating. When you sing or speak you make the little cords in your throat tremble, and when a kettle sings we may be sure that something is vibrating somewhere. This sets the air round it vibrating, and if it vibrates quickly enough we can hear it sing. If you only had a stick in your hand, and could turn it quickly enough in the air, you could make the stick sing.

Now, kettles do not always sing quite the same tune, and that depends upon a number of things; but at any rate we can understand that, as the water gets hot and begins to boil, it is turned into water-gas, or water-vapor, and it has to force its way out through the spout, and past the lid of the kettle. As it does this it sets various parts of the kettle trembling, and so the air is made to tremble, and so the drum-head, or window, in your ear is made to tremble, and your brain feels this, and you say the kettle is singing.

It is the pressure of the gas coming out that sets the kettle trembling. When you speak or sing you nearly close your throat, and then squeeze the air in your lungs through the small opening; and it is the pressure of the gas that sets your vocal cords trembling. So the kettle sings just as you do.

WHY LIGHT SEEMS RED WHEN WE SHUT OUR EYES

Eyelids cannot stop all light from coming through to the eyes—that is to say, they are, in a small degree, transparent, and enough so for the sunrise to waken the birds, even though their eyes are shut. Yet, when you look at the window with your eyes shut, what you see—very faintly, but still you see it—is a red color. Can you guess why this is? It is because the light that is able to pass through your eyelids has to pass through the red blood which, of course, is always in your eyelid. Now, this red blood keeps all the other colors that go to make up the white light, but lets the red color come through it, and that is why we see red with our eyes shut in the light. If our blood were green, we should see green.

CAN WE SEE EVERYTHING?

There are just two sorts of people in the world—the foolish, who think they see all there is to see, and the wise, who know they do not. This applies to seeing with the eyes of our heads, and to seeing with the eyes of our minds—which you mean when someone explains something to you, and you say: "Oh, I see!"

One of the greatest and wisest men who ever lived said that the highest knowledge a man could have was to know that he knew nothing—nothing, that is, compared with all that there is to know. For this, and other great sayings, this wisest of men—his name was Socrates—was executed by his fellow-citizens over 2000 years ago.

Even with actual seeing, and the best and brightest eyes, we see only a little of what is there, and usually see only its surface. That is why insight is such a good word for wisdom: it means that the eyes of a man's mind see into a thing. Then our eyes see only certain kinds of light. There are other kinds, which are darkness to us, yet we know that they can be seen by the eyes of ants, and also they can be seen by the lifeless eye of the camera, which has seen for us hundreds of thousands of stars that our eyes have never seen, and never can see.

DO WE SEE WHAT IS NOT THERE?

Besides not seeing most of what is "there," our eyes often see—or think they see—what is not there. Some of the most remarkable events in history have been due to mistakes of this kind. One of the great duties of the reason is to judge of what the senses, like eyes and ears, tell us, so that we shall not be deceived, or so that we shall learn all the more from our mistakes.

DOES LIGHT WEIGH ANYTHING?

If light were made of a shower of little sparks or specks, as Newton thought, then each of those must weigh something. Light, however, we know, is not matter at all, but a wave in the ether. So it has no weight. But that is not the whole story. Our study of light teaches us that it ought to have the power of pressure, which, in its results, comes to the same thing as weight. Thus, if you have a balance, and equal weights on each side, and then make a beam of light play down on one side, it ought to press down that side of the balance, just as if a weight had been added.

This is what was taught by a noted scientist, Clerk-Maxwell, many years ago, before this pressure of light had been proved. He foretold not only that there must be such pressure, but how much it must be. We can now show that pressure by experiment, and have found that his prediction of its amount—though he had never seen it at all—was right.

It is possible to prepare what is really a balance delicately hung on a thread of quartz, and to see that when a ray of light plays on one side of it, at once the balance turns as if you had touched it with your finger, or thrown something against it. This pressure, which is so like weight in its results, though it is not weight, is sometimes called light pressure. But it is common not only to the light that we can see, but also to the other radiations or rays in the ether which we cannot see. The proper name for it, therefore, by which it is now known everywhere, is not light pressure, but radiation pressure.

WHY THE SNOW IS WHITE

You might have asked also why is foam white when a wave breaks. In both cases we know that we are dealing with water, and yet, instead of being transparent, which means that it lets the light through, it is white. We understand at once when we find out what snow and foam are made of, or rather, what is the state of the water that makes them. In the case of snow, the water is frozen and forms tiny little crystals of beautiful shape.

These all lie loosely together, forming the snow, and though, if you could take one of them by itself, light would go through it just as it will go through a piece of clear ice, or many other crystals, yet when you have a heap of crystals lying together, all turned different ways, they throw the light back in all directions, just as salt does. They do not keep any part of the white light that falls on them, but throw it all back, and so snow is white. But, of course, if you have colored light falling on the snow, then the snow throws back that same color, and this gives some of the most wonderful sunset effects upon snow-covered mountains.

WHAT CAUSES A LIGHT TO BE YELLOW

What we call white light is made up of a vast number of lights of different colors all mixed together in just such a proportion that our eyes call it white. It is almost as if every note on the piano were played at once—with the difference that if this were done our ears would call the sound unpleasant; whereas, when our eyes see all these different kinds of light at once, the result is pleasant. The reason why it is pleasant is that this is the kind of light which the sun gives, and so through long ages our eyes have become suited to it. Now, yellow is just one of the colors that go to make up white light. The waves that make it are quite well known, and are rather low down in the scale of color, like a low note on the piano; while blue, for instance, is high up in the scale, like a high note. Though we say that the sun gives white light, yet really there is rather too much yellow light in sunlight for the result to be quite white.

What makes the rainbow

The rainbow is made by drops of rain; it is due to the reflection of sunlight from drops of water hanging in the sky. As the sunlight passes through the raindrop, and is reflected from the inside of the back of the raindrop, it is broken up into its various parts, which correspond to the various colors of the rainbow.

White light, we know, is a mixture of many colors. The light waves corresponding to these colors differ in the extent to which they are bent by passing through such a thing as a raindrop, and so, when they come out of it, they are sorted out, so to speak; and what was white light on going in, comes out as a band of several colors. Thus, what we see in the rainbow is really a natural spectrum of sunlight—the light spread out in a band of the various colors that make it up.

Where the rainbow ends

As we trace the rainbow down on each side it seems to touch the earth, and there are stories of children who have set out to find the end of the rainbow. But the rainbow ends nowhere, for it is a mere appearance in the sky, due to tiny drops of water, and it "ends," if we are to use that word, simply where the drops of water end that are so placed as to reflect the sunlight in this way to our eyes. Really no two people see exactly the same rainbow. They could not do so, unless their eyes were in the same place. And as we move, the bow we see moves with us.

Why spinning lights make rings

When black and white have an equal chance, the white conquers the black, because the white is something and the black is nothing; black is simply no light.

The disk of a black and white top looks all white when you spin it under a bright light, because your eye remembers the white when the black comes round, and remembers it till the white comes round again! And the black lines make black circles because they catch the eye and the eye remembers them in the same way. It is the eye's way to see a thing for about one-fortieth part of a second after it has gone! If you spun the disk in the dark as fast as ever you pleased, and then had a sudden light that came and went very quickly, you would see the spinning disk exactly as if it were still—half white, half black, and with bits of circles instead of whole ones. In some lights, too, we see colors, probably because the eye gets confused and invents them.

A whole roomful of people may be astonished at this experiment. The eye sees what is really there, and then the light goes out, and so, though the eye goes on seeing for a little after the light goes, it gets no chance to have another look, and so do what it does when the light stays on. This proves that nothing happens at all to the disk to make the change when it is spun. It is the way the eye sees that deceives us. The eye goes on seeing one color even when another has come; it mixes them—and then we see a new color made of the mixture!

Why the center of a gas-flame is blue and the outside yellow

The color of a burning or a hot thing depends largely on the temperature of it. A white-hot poker is hotter than a red-hot one; and a white-hot star like Sirius is hotter than a red-hot one like Aldebaran or the sun. The outside of a flame is far hotter than the inside, and gives out a brighter light in consequence—like a hot star or a hot poker. The color is due to "red-hot" particles of carbon.

Now you will ask why the inside of the flame is colder than the outside, and the answer is easy. The outside of the flame is the part next the air—next the oxygen—which causes the burning. The inside of the flame has to be content with the very small amount of oxygen which gets to it, still unused, through the outer part of the flame. Where the burning is fastest and most complete, there the heat is greatest, and therefore the outside of the flame is hottest.

Why Telegraph Lines Hum

Anything that is stretched is apt to be thrown into vibration, or made to tremble, by the force of the air blowing against it. If it vibrates so fast as to produce the air-waves that our ears can hear, then that is what we call sound. This is what happens to the telegraph wires when they hum; and if we put our hand on the telegraph pole we shall feel that the wires vibrate strongly enough to set the whole pole trembling, too. If we think of the way in which our own voices are produced we shall see that the telegraph lines hum in exactly the same way as we hum ourselves. Something stretched, in each case, is made to tremble. When the air is quite still, you will not hear the telegraph lines humming.

Why the Sky is Dull When a Storm is Coming On

The light of day is almost all due to the sun. The stars are shining, of course, as they do all the time, but they are so far away that the light of all of them put together counts for nothing compared with the sun; nor does the light of the moon count for anything when it happens to be up during the day. Thus we may say that the light of day is due to direct sunlight and to skylight, which is sunlight reflected from the sky—that is to say, from the air. When a storm is coming on, clouds gather, and these clouds are thick and dense, so that they cut off the light of the sky, and so we say that the sky is dull. If we went up in a balloon above the clouds, we should find ourselves in brilliant sunshine, even when it was almost as dark as night to the people on the earth below.

Why We Have to Develop Photographs in a Red Light

We know that white light is a mixture of light of all sorts of colors—red, yellow, green, blue, and so on. Some of these lights of various colors have one kind of power, and some another. For instance, red light has far more heating power than violet light, which has practically none at all, while red light will soon show its power on a thermometer. Now, the kind of light that has the power of causing chemical changes, which is the light we see by, and the light we photograph by, is mainly violet light, or the violet part of white light. We can see, in a way, by red light; but red light has practically no influence on photographic plates. We may say that photographic plates cannot see red light, and so we can use it to develop them by, without fearing that the photograph of our faces or the walls of the room will be printed on the plates.

What Colors Stagnant Water

When water becomes stagnant various forms of life grow on its surface. Pure water alone will not support life; there must be some other things in the water, and perhaps a fatty or oily layer on the surface of it, before these things—mainly microbes—will grow. Their growth covers the surface of the water with very thin layers of matter from which the light is reflected to our eyes when we look at it. But it happens, as in many other cases, such as a soap-bubble or mother-of-pearl, that the light is partly broken up as it is reflected from these thin layers, or as it passes through them if we were to see the water from below; and so the colors are produced. The reason is that the waves of light, as they return, some from one layer of the surface, some from another, interfere with each other, and the proper name for this is the interference of light.

Why a pop-gun pops

The "pop" of a pop-gun is a sound, and all sounds are waves of a particular kind produced in air or in other things. If they are to be what we call sounds they must be the kind of waves that our ears are able to hear, and these are special, differing from waves of wind, because they are very short and quick.

The question, then, really is: How does the pop-gun cause the kind of air-waves that we can hear? And the answer is that air inside the gun is compressed and then suddenly released, when the gun goes off. As it is released, it naturally expands or spreads itself out again to fill the space it filled before it was compressed. This means, of course, that it gives a quick push, as it expands, to the air on all sides of it, and so it starts the wave of air, which spreads out in all directions, from the point where it started, and reaches our ears. The kind of wave is one which our ears hear as a very short, sharp sound. It is short because the cause of it acts for only a very short time, and the sound of it is best represented by the word "pop."

What makes the loud noise when a gun is fired

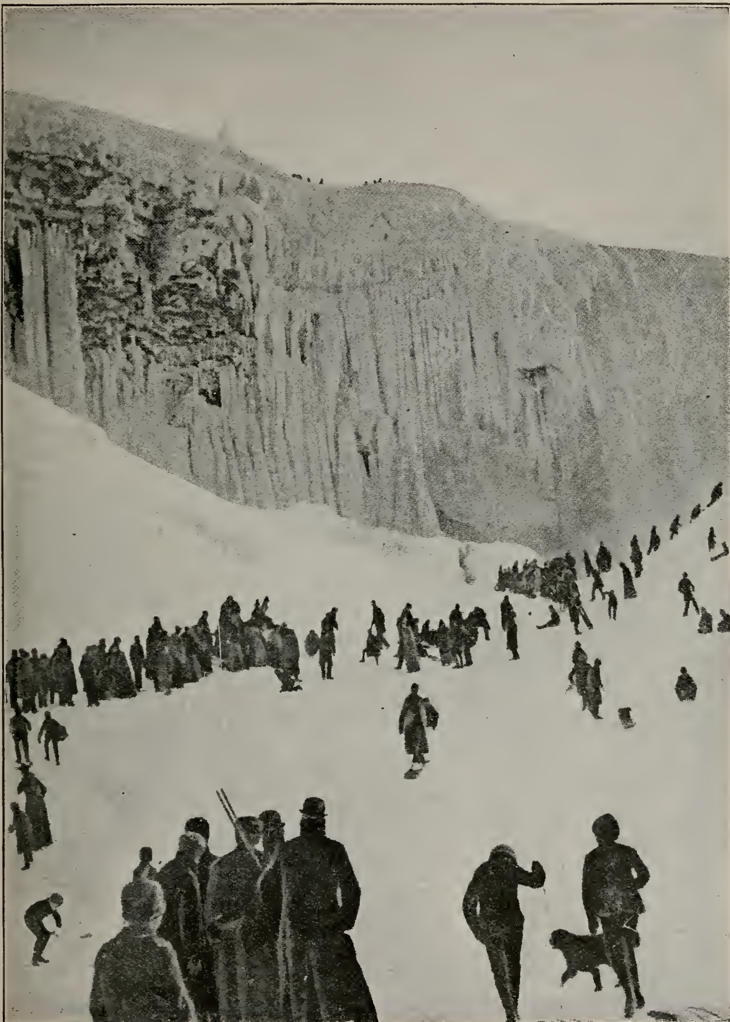
This noise also is due to an explosion, the sudden expansion of a compressed gas, as it escapes into the air from the space in which it was confined. Now, in a pop-gun, the gas that is compressed and then allowed to expand is air which already exists as air. But there is no air or any other gas in a cartridge, and the question is: Where does the gas come from that makes the noise and fires the bullet when a gun is fired?

What happens is that we suddenly burn a powder which we have prepared of materials such that when they are burned a large quantity of gas will be produced, and it must be produced very suddenly, if the full explosive power is to be obtained. We have another great advantage in trying to make this kind of explosion, as we have not when we fire a pop-gun. That is that the gases produced are exceedingly hot, for they are heated by the burning which makes them. A hot gas naturally occupies a great deal of space—far more than a cold gas, and so when we fire a gun we suddenly produce a great quantity of hot gas in a tiny space, which is not nearly sufficient to hold it. If this were done in a closed box it would burst the box, but in the case of the gun we have prepared a way out for it—only that we put a bullet in the way. Out comes the gas, driving the bullet before it, and as it expands it starts the wave of sound we hear.

Why houses seem crooked when we look above a street fire

Light is always bent in some degree by the various things through which it passes—as when it passes through the air to our eyes from a star, or as when a stick, half in water, seems to be bent. Now so far as light is concerned the air is different according to its warmth. Warm air is less dense than cold air, and when light passes from one to the other, in either direction, its path is more or less bent. So when we look at the houses through the hot gases that rise from a watch-fire, the light, as it travels from the

REMARKABLE SPECTACLE OF A FROZEN CATARACT



This is one of the most wonderful things ever done by Jack Frost. It is a picture of Niagara in winter. No man's hand, no machine ever made by man's hand, could stop the mighty rush of Niagara over the cliffs; but winter does it, and silently ends the roar of the waters. When winter comes parts of the great Niagara Falls are often frozen over, and then the sight is one of the most beautiful in the world. Part of the frozen falls is shown in this photograph. Imagine enormous icicles, far thicker and taller than the pillars in any cathedral, all sparkling like diamonds in the sunshine. The frozen spray covers all the rocks and trees near the falls with wonderful hoarfrost, looking like beautiful moss and ferns of glittering white houses to our eyes, is bent in passing from the cold air through the hot gases, and is bent a second time in passing from the hot gases through the cold air again.

Also, as the fire does not give off the same quantity of gas at every moment, the light is bent in different ways, and not only do we see the houses crooked, but they seem more or less crooked as we keep on looking at them. This bending, or breaking, of the rays of light as they pass from one thing to another is called refraction, which simply means breaking, and is very important in every way. Just as you see the houses crooked when you look at them through the gases from a fire, so we see all the stars crooked when we look at them through the air. The light from the stars is bent as it passes through the air, and so we do not see stars where they really are, but always a little distance from the real place, because of the refraction of their light.

WONDERS OF AIR, FIRE AND WATER

WHY WE CANNOT SEE THE AIR

THE reason why we cannot see the air is that it is transparent, like glass—that is to say, it lets light go through. It affects the light in some ways; for instance, light coming to the earth from a star is bent a little as it travels through the air, so that we never see the star where it really is. But directly we change one part of the air as compared with the air around it, so that it bends the light a little more or a little less, then we notice something.

In a sense you can see the air moving sometimes above a hot gas-jet or a field on a hot summer day. Also it is quite easy to change air so that you can see it in another way. We can make it cold so that it becomes like water, we can see it as you see water, and we can even freeze it so that it looks and can be seen just like ice. The air, fortunately, has no color in itself, so it does not alter the color of the light passing through it—which would mean altering the color of things.

WHAT THE AIR IS MADE OF

The air is a mixture of several gases, and these are all colorless and transparent. Among the gases in the air are carbonic acid gas, which we give off when we breathe—and which is food for plants—and also a small amount of various other gases found only a few years ago. Most air also contains not a little water in the form of a gas or vapor. But all these taken together do not amount to very much. Very nearly the whole of the air is composed of two gases only; about four-fifths are made by a gas called nitrogen, which is very valuable to plants and therefore to us, and the remaining fifth is made by the wonderful gas, oxygen, by which we live every moment of our lives.

The air of crowded indoor places, or the air that you will find in a bedroom in the morning if only a single person has been sleeping in it all night with closed windows, is very different from fresh air or open air. It has the same things in it, but it has a great many other things; it has too much carbonic acid gas and too little oxygen, and it has all sorts of poisonous gases which the sleeper has given off in his breath and from his skin.

WHAT A DEWDROP IS

At night when the dew comes, great dewdrops frequently hang upon a spider's web stretching across the trees. Those tiny beads of water look very simple, but it took wise men hundreds of years to find out what they are. Then they found that a dewdrop is part of something very important indeed. There is in the air a great deal of moisture, which cools the rays of the sun so that we are not burned on a hot summer's day. At night, when the earth passes out of the sunlight, the earth lets out the heat that it has stored up by day, and the moisture causes the heat to escape slowly. If it did not the earth would suddenly become so cold that we should be frozen to death in a single summer's night.

Well, in the evening, when the earth begins to give off its rays of heat, the moisture in the air drinks in the rays, so that the moisture becomes warmer than the earth and the grass and the flowers, from which the heat rays have come. The grass and the flowers become very cold after losing their heat, and as they grow cold they chill the moisture near them. The moisture, when it becomes cold, turns to real water and falls towards the ground like rain, and the blades of grass, or the leaves of trees, or the spider's web, catch the drops as they fall, and the water, trying to keep itself together as much as it can, gathers into tiny beads.

These are the dewdrops.

Why the sea is salt

It is the rivers that make the sea salt. The sea was first made by the water that was in the air falling into all the deep places on the earth. That was the first rain that ever fell, and it was quite fresh—that is to say, there was no salt in the water, but the first salt in the sea was taken directly from the crust of the earth, and later added to by rivers. There are all sorts of salt in the earth, and as the rivers run into the sea they take the salt out of the earth they run over and carry it into the sea, although when the sun draws up the water again and makes the rain it does not suck up the salt with it.

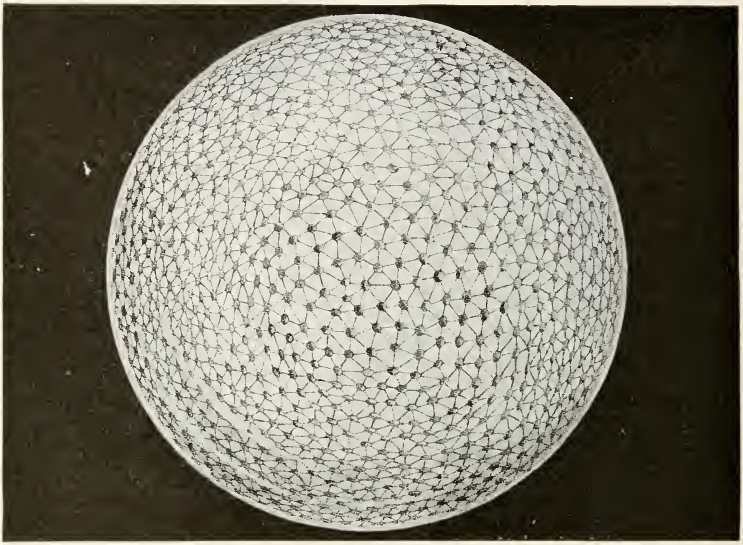
You have just learned that it is the water drawn up by the sun that makes the rivers, and so the rivers start with fresh water; but by the time they have reached the sea they have taken quite a lot of salt, which they add to the salt already in the sea. So from day to day, and from age to age, the sea gets salter and salter; and we guess the age of the sea by noticing how much salt the rivers carry into it every day.

Why a soap-bubble rises and falls

It is quite true that if a soap-bubble lasts long enough, and does not burst too soon, it will begin to come down again after a little. The simplest explanation of this would be to remember the case of a balloon filled with hot air. It goes up, for a time, and then it comes down again. It goes up because the hot air inside it is lighter than the air around it, and, being lighter, must rise, just as hydrogen would have to rise. When it cools, then the weight of the covering of the balloon brings it down again. Now, a soap-bubble is really a little hot-air balloon, for the air that fills it is warm air from our lungs, and the air is so much lighter than the air outside that it goes up with force enough to carry the weight of the water that makes the skin of the soap-bubble. But this cannot last long, for water is a very good conductor of heat, and the skin of a soap-bubble is very thin, and so the heat from our breath that is inside the soap-bubble soon escapes, and the bubble becomes as cool as the air around it. Then there is nothing to hold up the water of the bubble, and it begins to come down. It is interesting to know that the early experiments for ballooning were actually made with soap-bubbles.

How a soap-bubble holds together

The soap-bubble is really a bubble of water—the soap merely helps; but, as the bubble is made the water is spread out into a sort of skin, and for a time, at any rate, that skin holds together because the particles of which the water is made hold on to each other what men of science call surface tension. Tension simply means stretching, and so the name hints at the forces of stretching and holding, which are shown when the matter that makes up one surface meets another. This question is very difficult.



THE WONDERFUL WAY IN WHICH A SOAP-BUBBLE IS MADE TO HOLD TOGETHER

This picture shows us how a soap-bubble holds together. There are millions of tiny molecules of water, like a wonderful net of beads, blown out into ball shape by the hot air inside. Of course, no microscope could show us a bubble like this, but the picture gives us an idea of how a bubble is made. The molecules of water should really be infinitely smaller and greater in number than they are here, and the lines between the molecules are merely drawn to suggest the way in which cohesion draws the molecules together. There are not really any lines.

and avoid the air on both sides of them. Of course, the bubble cannot last long, for the water which makes it runs down by the force of the earth's attraction until it becomes too thin, and then it bursts.

The point for us to remember just now is that the soap-bubble merely raises a question as to the way in which the surface of a thing behaves when it is next to the surface of something else. It is really a question of

Why water quenches fire

Water puts out fire for two good reasons. First, if a thing is covered with water, the oxygen of the air cannot get at it to burn it. But that is not nearly the most important reason why water puts out fire. It is that water has a great capacity for heat, and can hold a great deal of it. It takes so much heat into itself, and so quickly, that it lowers the temperature of the burning thing so that it can no longer burn.

Why a River Runs into the Sea

The surface of the earth is not level. It has mountains and hollows, and hills and valleys. Now, everything is always drawn towards the center of the earth, because the earth pulls it, as the earth pulls a ball if you drop it from your hand, or stops the ball and pulls it back again when you throw it up. So all the water in the world is always trying to run to the lowest places to get as near to the middle of the earth as it can. The very lowest of all places are the great basins of the oceans and the seas, and that is why they are full of water. A river runs to the sea for the same reason that drops of water run down a window-pane. All rivers run downhill all the time, even when to our eyes they seem to be running on the level.

But the next thing you will ask is, where does all the water come from, and also why does the sea not get too full? You will find that a wise man in the Bible long ago said: "All the rivers run into the sea, yet the sea is not full; unto the place from whence the rivers come, thither they return again." Now, that is the true answer, though perhaps you cannot understand it at first. The water returns to the places where the rivers came from because the heat of the sun sucks it up into the air from the sea, and the wind carries it over the land, and it makes clouds and falls as rain on the hills and the high places, where it is gathered into little streams and makes the rivers again, doing useful work all the time as it flows. That is why the sea is not too full and does not rise and wash away the land even though all the rivers in the world are always running down into it. Did you ever think that a river might be tired of running down such a long way to the sea? A poet thought so once, and said:

"Even the weariest river
Winds somewhere safe to sea"

HOW THE RAIN RISES FROM THE SEA, AND HOW THE RIVERS CARRY IT BACK TO SEA

The sun draws up the water from the sea as moisture, which mixes with the clouds and is carried overland by the wind, as the arrows in this picture show. When the air cools the moisture becomes water again and falls as rain. The rain on the hills runs down into the valleys and along the rivers back to the sea, because all water, like everything that can run, tries to find the lowest place on the earth, which is the bed of the sea.

What Makes the Water Boil

To understand this you must know what it is that forms the bubbles when water boils. If you hold a cold plate over boiling water you will find drops of water form upon it, though you can see no water passing upwards between the surface of the boiling water and the plate.

The truth is that, though we always think of water as something liquid and wet, just as we think of air as something that is always a gas, we have no right to do so. Air and water, and everything else, can exist in three different forms, either solid, or liquid, or in the form of a gas. Air, for instance, is usually a gas, but it is not very difficult to make air liquid, so that it looks just like water, or to make it solid, so that it looks just like ice. Water happens to be usually fluid, but we all know that when it is cold it becomes solid, ice being simply solid water; and we must now learn that, when it is hot enough, water becomes a gas just like air. Indeed, the air contains a quantity of water-gas, or water-vapor, as it is usually called, and when we find the weather close and "muggy," as we say, it is usually because there is more of this water-vapor in the air than we like.

When water boils, then, the bubbles are bubbles of water-gas or water-vapor, and if this vapor strikes a cold surface like a cold plate, it becomes liquid or wet again.

One of the things that decides whether anything shall be solid or liquid, or a gas, is heat; and so, of course, the simple answer to the question, "What makes the water boil?" is heat. We apply heat to water, and it begins to turn into gas, which makes the bubbles.

Why water boils away

If we go on boiling the water, of course we boil it all away as gas, until there is none left. In an ordinary way water always begins to boil when it is at a certain temperature, and this is called the boiling-point of water. It is not possible in an ordinary way to have water any hotter than this point, no matter how much heat you apply to it. The result will be not to make it any hotter, but simply to turn it into gas until it is all gone.

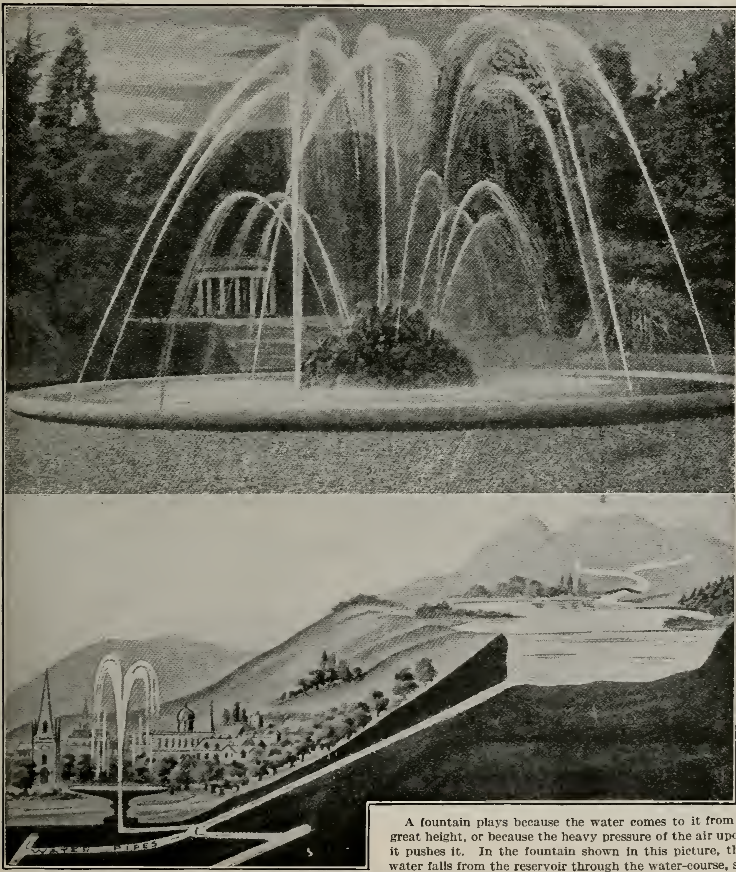
One of the things that decides the boiling-point is the pressure of the air, at the bottom of which we live. Now, if you take some water up to the top of a high mountain, the pressure of air is much less, because there is not so much air above you. If now you heat the water, it begins to boil when it is nothing like so hot as it needs to be made before it will boil at the bottom of the mountain; because on the mountain there is less pressure of air squeezing the water, and so it can more easily expand into bubbles of gas. So if you put an egg in the water at the top of a mountain, you may boil and boil as long as you please, but you will never boil the egg hard, simply because, however long you boil, you can never make the water hot enough to make the egg hard. The water simply floats away as gas long before you can do so! You might almost drink boiling water if you were on a very high mountain.

Why air is fresher after rain

There are several reasons for this. For one thing, the rain washes the air, as water will wash anything else. If the air has contained a number of smoke particles, as it does in large cities, the rain has reduced their numbers by carrying them down with it as it fell through the air. Thus the rain helps to rid the air of the sulphurous and other gases which are given off by these smoke particles. Then again, it now seems that the falling of rain often, or always, depends in part on electrical charges in the air, and these charges may help to produce small quantities of the gas called ozone, a variety of oxygen, which has a fresh smell of its own. Then rain cleans the roads and washes away all sorts of things which give off unpleasant odors. We do not realize the extent to which rain is a cleanser in cities; and we must remember that our noses are usually only a few feet above the surface of the street, so that they are exposed to whatever arises from them. A few hundred feet higher, the air would smell very different.

Why the fountain plays

The puzzling thing about the fountain is that the water comes upwards, though we know that water always tries to fall; it falls because the earth pulls it. Now, something must be pushing the water up more than the earth is pulling it down, and the question is what? The answer is that the water in the fountain is being pressed upon at the end which we cannot see by the air, which is really very heavy; and the fountain is so made that the air pushes one end of the water and makes the other end spout up. If this sounds puzzling, you have only to look at a syphon of soda-water, which is a fountain. If the spout turned upwards instead of downwards, it would be just the same



A fountain plays because the water comes to it from a great height, or because the heavy pressure of the air upon it pushes it. In the fountain shown in this picture, the water falls from the reservoir through the water-course, so that the water runs until it finds the air again, when the pressure is released.

as any other fountain. The air, or gas, inside the syphon presses hard on the soda-water below it, and directly it gets a chance the soda-water rushes up the tube in the middle of the bottle and out at the spout. When you make the soda-water run, you do just the same as the gardener when he makes the fountain play.

Why raindrops are round

First, why does the rain form drops at all? We know now that there is always something which we may call a particle of solid stuff in the inside of a raindrop, and when the drop was made it was made by the water-gas or water-vapor in the air turning liquid upon this solid speck, as steam from boiling water turns liquid on a cold plate held above it.

But you want to know not merely why the raindrop forms at all, but also why, when it is formed, it is so nearly round. The answer is the same as the answer to the question why water forms in round drops on a plate, and the question why it runs in drops down the window-pane when it rains. When water turns liquid it really consists of tiny parts, each of which is itself a part, or particle, as we say, of water, just as a human crowd is made of men and women.

How a balloon keeps up

This question is really the same in its explanation as the question why does a stick float. If there were no air, the balloon would drop like a stone, just as if the water all disappeared from the sea, the fishes would drop to the bottom. Things float in the sea, or on the surface of it, because the amount of stuff in the space they occupy is less than the amount of stuff in the same space of water. The less dense thing always tends to lie above the more dense, and if the things in question are gases or liquids, they always will follow this rule. If you pour hot and cold water into a bath or into a tumbler, the hot water will lie at the top and the cold at the bottom, because water is less dense, and therefore less heavy, when it is hot than when it is cold. Gases behave in exactly the same way. Hot air behaves in the midst of cold air just as hot water behaves with cold water —it goes upwards.

Now, if you put the hot air into something very light, the hot air, as it goes upwards, will take that something with it. The first balloons were made in this way. Two Frenchmen, brothers, made balloons of silk and linen and filled them with hot air and smoke, and after making balloons which carried animals, they persuaded some men to be carried in this way. You understand that this was simply because hot air is less dense than cold air, and therefore lighter.

What makes the balloon go

But, of course, hot air gets cold, and then your balloon will come down. So we ought to fill our balloon, if possible, with some gas or other which, even when it gets as cold as the air around it, is still lighter than the air. Nowadays balloons are filled with such a gas. Its name is hydrogen, and it is extremely light; indeed, it is quite the lightest thing we know. Oxygen, for instance, is sixteen times as heavy, and nitrogen fourteen times as heavy, and as the air is a mixture of these, hydrogen, if let loose in the air, will fly upwards at once, and, if you have enough of it, it will carry not only a covering to keep it together, but also many people in a car hung from the covering. The interesting thing for us now is simply that it is so very light and therefore is more useful than anything else for filling balloons.

What makes a kite fly

The case of the kite proves to us that the air has a great power of holding things up, since the kite has no wings, and yet it does not fall. The air supports it. If you took all the material of which a kite is made and rolled it into a tight ball, it would drop like a stone.

So it is not that the kite is made of something lighter than the air. A balloon flies, we know, because it is filled with something lighter than air but the kite has no light gas inside it, and yet it does not fall. The reason is that it is spread out as wide as can possibly be, so that it may have a large surface for the air to support it. But, of course, if there were no air at all the kite would drop at once, just as the bird would, whether it were flying or not. Neither the kite nor the bird could rise or swim in nothing. Now, the Latin word meaning empty is vacuus, and a place that is quite empty, even of air, is called a vacuum.

What clouds are made of

One of the reasons why we know that there is no water, or scarcely any water, on the moon is that we never see the slightest hint of a cloud when we look at it. If there were people on the moon looking at the earth, they would constantly be finding that the face of the earth was hidden from them by clouds. One of the things which we are studying now in the wonderful planet Mars is as to whether there are any clouds to be seen there, because, if there were, that would help to show that there is water on Mars. Hence, clouds are made of water; or, rather, a cloud is made of many drops of water, which, when they fall, we call drops of rain. Men who study these things are now beginning to learn how it is that sometimes these drops stay in the cloud, and sometimes they fall and make rain. The water has come from the seas and great lakes, and has been drawn up by the sun.

Why coal burns and stone does not

The simple answer to this is that stone is burned already and cannot be burned twice; but that answer wants explaining. What happens when a thing burns is that it combines with the oxygen of the air. When it has taken up all the oxygen that it possibly can and has combined with it, then it is completely burned, and can burn no more.

We watch a candle, let us say, burning, and we are deceived because we do not see the result of the burning. The result in the case of the candle is a number of gases which we do not notice, real though they be; but when various other things are burned the result is not a gas at all, but sometimes a liquid and sometimes a solid.

When the hydrogen gas is burned or combined with oxygen, it forms water. When the element silicon is burned or combined with oxygen, it makes a solid, and most rocks and sand are made of this. An ordinary stone or sand is really silicon which is already burned. But coal is made mainly of carbon which is not yet burned. Burned carbon—that is to say, carbon combined with oxygen—makes the gas called carbonic acid, and that gas cannot be burned any more than a stone can, and for the same reason. Both are burned already.

Why asbestos does not burn

Asbestos is already burned, like stone or sand, and can be burned no more. It is also very difficult to melt, and will not melt with the heat of an ordinary flame; and so it can be used for many purposes—to line safes, for gas-stoves, and so on. The very word is simply taken from the Greek, and means "unburnable." Of course, both in this case and in the case of stone and sand, we cannot doubt that long ages ago all these things were made by being burned or combined with oxygen when the earth was a very different place from what it is now.

What smoke is made of

Smoke is the result of imperfect burning. Most of the things from which we get so much smoke—like coal—if they were properly burned, would form nothing but gases, which we could not see, and which would very soon fly away and do no harm to anybody. But in order to burn coal properly some trouble and care are required. When we burn coal in an ordinary fire, we do not supply enough air to it. We put the fresh coal on at the top instead of at the bottom, as we should, and so we only partly burn the coal, and small specks of it, unburned, are carried up in the draft, and make smoke. The chief stuff in smoke is simply coal, in specks of various sizes. But the trouble is that a great deal of oily stuff comes out of the coal, and covers the specks of it in smoke, so that these stick to things.

At present the smoke makes black fogs in many cities, and cuts off a great quantity of the daylight by which we live, besides making everything dirty, destroying plants and trees, and filling our lungs with dirt which we never get rid of. There are few things about which we are more careless than smoke, and, besides, we waste a great deal of our fuel.

Why flames never go down, but up

We might think, if we had not noticed, that this question was not true, and that flames only go upwards because a gas-jet, for instance, is always directed upwards. But the question is quite true, even in the case of a gas-jet that is directed downwards, for we find that then the flame turns upwards. If we must have a flame going downwards or sideways, then we must have a draft to blow it, just as the wind will blow the flame of a match in any direction.

But even where there is no draft at all in any direction, and when we burn something without sending any gas in any particular direction through a hole, flames always go up, and never down, as the question says. And the reasons are: First, that the gases made in the flame are very hot, and, as hot gases are always much lighter than the cold gases that make up the air around them, the hot gases of the flame tend to rise; and, secondly, every flame, as the hot gases go upwards because they are so light, makes a draft for itself. As the hot gases go up, the space they leave is filled from below, and this goes steadily on, and so makes a draft.

Why hot gases rise

A gas-jet, properly used, may actually help to ventilate a room by making a draft; and every fire does the same thing, by increasing the natural draft going up the chimney. The gases which are produced when anything burns are themselves burned, once and for all; they can neither be burned again, nor can they help to burn anything else.

These gases consist chiefly of carbonic acid gas and water-vapor. They are both of them completely oxidized—the carbon of the one and the hydrogen of the other are combined with all the oxygen they can hold. Nor will either of them give up its oxygen for the burning of anything else. Thus, if hot gases did not rise, and so make room for fresh air—which really means fresh oxygen—nothing could burn for long; for nothing can burn in an atmosphere of carbonic acid and water-vapor, and such an atmosphere would at once surround every burning thing if hot gases did not rise.

Why the sea looks sometimes blue and sometimes green

On a black night, when there is no light for the sea to reflect, the sea looks black. When the sky is gray, the sea reflects the light that falls upon it, and looks gray. The color we usually think of as the color of the sea is blue, because the sky is blue, or ought to be; and if it be blue light that falls upon it, it is blue light that the sea reflects.

Yet sometimes the sea is green, though the sky is never green. Parts of the sea are shallow, especially near the shore, and may be so shallow that some of the light from the sky may pierce the water, reach the bottom, and be reflected from it to our eyes. So, of course, the light will be changed, partly according to the color of the bottom of the sea, and partly because of the greenish tinge of sea-water itself. Besides all this, we have to remember that the same part of the sea on a coast we know well may be of a different color on different days, even though the water is the same and the color of the bottom is the same, because the sun is in a different part of the sky, and so the light strikes the bottom differently, or because the sky is clouded, and so the light which reaches the sea from the sky is different. Thus, there are many different things which will affect the color of the sea, and that is why its color changes so often and is so beautiful to see.

What Changes the Course of the Wind

Like almost everything else, the air is always moving, more or less, and the changes in the direction of its movements are due to many different things. There is, for instance, the movement of the earth on itself, and also its changing position in regard to the sun as it goes round the sun. These movements mean that different parts of the earth are exposed to the sun at different times; and that means, of course, that different parts of the air are exposed to the sun at different times. When the sun shines on the air it makes it warm, and warm air is lighter than cold air, and will rise, while cold air will flow in to take its place.

But there is a great deal more in it than this. Besides the fact that the surface of the earth is not smooth, but has mountains and hills that turn the wind as the earth turns, and tracts of water which cool hot air as it passes over them, there are all sorts of electrical changes always going on in the air, and these probably affect its weight—perhaps even the proportions of the various gases in it—even as much as the heat of the sun affects it. You can scarcely ask more difficult questions than these about wind, rain, and weather.

Why Flowers Smell Sweeter After Rain

Where there is any vegetation rain has a great influence in making the air smell fresher, for water has a special power upon the activity of many kinds of vegetable life that produce pleasant scents. We say that the rain brings out the fragrance of the flowers, and that is true. All life requires water, and all the processes of living creatures are helped by a good supply of water. When rain falls on flowers, and on many kinds of leaves, it sets going the chemical changes which result in the production of many pleasant odors which are added to the air, and so help to make it smell "fresh."

Could We Live Without Rain?

The good of rain is that it soaks into the soil and is sucked up by the roots of plants, which must have it if they are to live. If there were no rain there would be life only in the sea. In parts of the world where there is no rain there is little life. In this country we have no idea, just because we are so well off, how rain is loved and treasured and prayed for in other countries where there is not enough of it, or where it falls only at certain seasons of the year. We must think of rain then as something that cleanses the air, nourishes the vegetable life upon which our own life depends, and insures a supply of fresh water all the year round in every part of the world where sufficient rail falls.

WHY THE BEDS OF RIVERS CHANGE

The earth's crust is shrinking all the time, as the interior cools and shrinks beneath it. This means that the land changes from age to age, and one consequence of this is that often the water of a river finds that its steepest and quickest course to the sea is different from what it used to be, and so the river-bed changes; the old one is deserted by the waters, and a new one is formed.

But the water itself, as it flows, rubs and melts away the earth it flows over, and so grinds a deeper and ever deeper bed for itself. Thus it gets less and less likely to desert its old bed the longer it flows there.

WHY IT IS EASIER TO SWIM IN SALT WATER THAN IN FRESH

Swimming really has two parts—one is to keep up in the water, and the other is to move along in it. The question is: Why is it easier to keep up, or to float, in salt water than in fresh? The answer depends wholly on the heaviness of our bodies as compared with the heaviness of the water. Our bodies are more than three-fourths water, but most of the rest is heavier than water. The fat of our bodies is lighter than water, and so helps us to float.

Now, fresh water is less heavy than salt water, and so our bodies, though only a little heavier, tend to sink in it. Ordinary sea water is heavier than fresh water, because it contains a lot of salts, just as the water of our own bodies does; so we find it easier to float and swim in sea water. But in some parts of the world there is water that is much salter than even sea water; this is the case, for instance, in the Dead Sea, and the Great Salt Lake in Utah. There is so much salt in the water of the Dead Sea that it is actually heavier, on the whole, than our bodies are, so you cannot sink in the Dead Sea! On the other hand, there are some liquids much lighter than water, and if a man were to fall into a lake of one of them he could not swim at all, however good a swimmer he might be; his body would sink like a stone in such a light liquid.

WONDERS OF EARTH, SUN AND STARS

WHY AN APPLE FALLS

NO one in the world knows why an apple falls to the ground. We simply know that the earth and the apple pull each other together—the apple, being small, moving a long way, and the earth, being large, moving a very little way—no one knows why they pull each other. But everything in the wide world pulls everything else in this way, as was proved by Sir Isaac Newton. It may be that as a boy while lying under an apple tree in his father's garden, saw an apple fall, and thought. "The earth pulls the moon and keeps it running round her, just as it pulls the apple," he said. If the moon stopped moving round, it would rush to the earth as the apple does. So he discovered the law of universal gravitation.

Now, the more stuff there is in a thing the more strongly it is pulled by everything else. So the earth should pull a big weight more strongly than it pulls a small one, and it does. Then the big weight will fall quicker than the small one, men thought.

They forgot that it takes a stronger pull to pull a heavier weight; the heavier it is, the stronger the pull, but the more the pull has to do. Therefore, a heavy weight and a small one fall at the same rate.

How the Leaning Tower of Pisa Stands

In the town of Pisa, in Italy, is a famous leaning tower, which has stood for hundreds of years.

There is nothing in the whole world quite like the leaning tower of Pisa. Its building was begun more than 800 years ago, since the people who lived in Pisa wanted to have a tower as fine as the great bell tower of Venice. Yet, though the tower of Pisa met with a strange accident that might have ruined it, it still stands, and the tower at Venice fell down a few years ago! We know now that the tower was not meant to lean, though it is 13 feet out of the straight line!

The tower was built on wooden piles, driven into ground so soft that when the tower was little more than begun it began to sink on one side. There is no other tower in the world that leans so much as this at Pisa. The tower does not fall because, as they went on building it, they made it in such a way that if you dropped a straight line down from a certain point in the tower, called the center of gravity, which is equally balanced on all sides, by the weight of the tower, that line would touch the ground within the foundations of the tower. If the line reached the ground somewhere outside the tower, it would fall.

But the tower is very interesting for another reason, and the reason is that its peculiarity was used by one of the greatest men who ever lived, in order to make one of the most famous experiments. This man was the great Italian astronomer Galileo, who, more than 300 years ago, was a professor in Pisa, and was thinking for himself. The great Greek thinker Aristotle, nearly 2000 years before the time of Galileo, had declared that if you took two balls of the same material, one small and the other large, and dropped them at the same moment, the large one would reach the ground first. If it was ten times as heavy as the small one, he said, it would fall ten times as quickly.

Nowadays, when anyone says anything like this, we always make the experiment at once, and let Nature decide. But in the old days very few men thought about this; they chose some great man, and made him their authority. So for nearly 2000 years everyone believed and taught what Aristotle had said about falling weights, and no one made the experiment to find out the truth.

At last, however, came Galileo, and he was thinking for himself. He said that the two weights would fall in just the same time, even though one was heavy and the other light, and everybody laughed at him. It is always a hopeful sign when everyone laughs at you—at least, no one has ever done anything in the world who has not been laughed at. "Very well," said Galileo, "come and watch me make the experiment." So one morning, before the assembled university, professors and students, he ascended the leaning tower, taking with him a ten-pound shot and a one-pound shot. He let them go together. Together they fell and struck the ground.

And so, you think, everyone praised Galileo for having found out a new truth, and he was famous ever afterwards. But one of the lessons we have to learn is that that is not what men usually do in cases like this. What really happened was that everybody abused the young man for daring to differ from Aristotle.

They started hissing at Galileo's lectures, and in a very short time he had to leave Pisa—turned out for finding a truth. The same thing happened to many great men before Galileo, and has happened to many since.

Where the stars stay in daytime

The stars in the daytime are just where they are at night, and if something could be put over the sun we should see them again. Something is put over the sun sometimes, for the moon comes in the way, so that for a time it cannot be seen, even though it is daytime and there are no clouds in the sky. When that happens, one of the most wonderful things in the world is to see the stars "come out again." They were there all the time, shining as brightly as ever, but the sun is so very much brighter to us—because it is very much nearer—that we could not see them.

When you are listening to thunder, or to a cannon, you do not hear the quiet sound of your own breathing, although the thunder is far away and the breathing is near; and just as the great noise swallows up the little sound, so the great light of the sun swallows up the little light of the stars. There is another way of cutting out the light of the sun so that the stars may be seen in the daytime. Men who work at the bottom of a pit or a well, and look up at the little bit of sky above them, see the stars almost as brightly in the day as in the night.

What keeps the sun bright

You would think that the sun is bright because it is burning—that it is an enormous fire. But when a thing burns, the stuff of which it is made joins with the oxygen of the air in which it burns. The sun, however, is actually so hot that nothing can join with anything else in it; nothing could burn in the sun. There are plenty of things which would burn there, and plenty of oxygen to burn them with, but they are kept apart by the heat. Also, even if things could burn in the sun, that would not keep it alight, but it would have burned out ages ago, and we should not be here.

Last century we found out to what agency the sun owes its heat and light. They come mainly because the sun is shrinking. It shrinks, or contracts, by gravitation — the power which makes every piece of stuff in the world attract all other stuff to itself. The sun has been shrinking for many ages, just as the earth has been shrinking. Indeed, long before the earth was formed, the sun was stretched out as far as the earth's present distance, and even as far as the earth's farthest brother, the planet Neptune. As the sun shrinks its parts strike each other, and their motion is stopped, and heat and light are produced, just as when one piece of flint is struck by another.

So it is gravitation that really gives us the heat and light which keep us alive. Astronomers have also come to attribute the presence of radium as a cause of heat. Probably the sun is also kept warm, as the earth, we know, is kept warm, by having in it some of the wonderful element radium, which produces heat from within itself.

How big the world is

The world is nearly round. From the North Pole to the South Pole, straight through the earth, the distance is about 7899 miles. A pole thrust through the center of the earth, from side to side, would measure about 7925 miles. The distance right round the outside is about 24,850 miles.

The round world is a vast mass of land and water, surrounded by air. It spins like a top, it travels round the sun, and it moves forward with all the stars in the heavens—forward and forward, forever and ever. So tremendous is the size of this huge globe, that the mighty range of mountains which we call the Alps are only likely the burrowings of a mole on the ground.

Now, if the Alps are so small in comparison with the size of the earth, how much smaller must man appear?

How man conquered the earth

Man conquered the earth, on which he is like an atom, because he is not content to stand still like the Alps. Though he is so much smaller than these mountains, he has a brain which enables him to triumph over the weakness of his body and the smallness of his size. He can move; he can think; he can manufacture.

You can imagine how, in the far past, our savage ancestors would watch birds sailing through the air over the deep waters, and long with all their souls to have that power of flight. For one of man's chief qualities is curiosity. Man is always wanting to find out things. And naturally the first thing he most wanted to find out was the kind of earth on which he lived. So our early ancestors looked across the waters, and dreamed of lands on the other side of the globe.

The curiosity of men is the beginning of geography, for curiosity led men to look about them and observe the earth. When they had learned to build ships, they sailed across the seas, visited many foreign lands, and returned with descriptions of those places and the people they had lived among. These descriptions we call geography.

Do people live on the moon?

We have seen only one side of the moon, because, as it goes round the earth, it turns slowly on itself, so as always to keep the same side turned towards us. But we are quite sure that there are no people on the moon, either on this side of it or on the other side, which we have never seen. People could not live on the moon because the moon has no air and no water. Even if people could live there without air or water, they would probably be burned to death in the daytime, having no air to protect them from the heat of the sun, and they would be frozen to death at night, having no air to keep in the sun's heat.

But possibly at one time there may have been humble forms of plant life on the moon, and some people suppose that there may be a little of this even now, for it is possible that there may be a tiny amount of air and water still left at the bottom of some of the deepest valleys in the moon. If there were a building on the moon as big as the Capitol at Washington, we should easily be able to see it through our biggest telescope, but there is not the slightest indication that intelligent beings have ever made a mark of any kind on the moon.

What the stars are made of

Not very long ago, a great thinker declared that this great question was one which men would never be able to answer, however long they thought and however hard they worked. Our telescopes could never tell us; the biggest telescope that could ever be made would never tell us.

It would only make the star look nearer and brighter, but would tell us no more what the star is made of than our eyes can tell us without a telescope. But now we have a wonderful instrument called the spectroscope by which we can study the kind of light that is given out by any star that we can see. And since we find that the light of the stars, thus studied, is exactly the same as the light given out by things we know on the earth when they are made hot, we now know that those same things are found in the stars.

So, the answer is that the same kind of stuff of which this paper, and your eyes, and our ink and pen are made are to be found in the stars. The stars are made of the very same kinds of stuff as the earth is made of. Of course, all the stars are not the same. Even with our own eyes we can see that some are redder and some whiter than others. Some have more oxygen in them, and some less, but the point is that it is oxygen, the same element as we breathe at this moment.

Why the stars twinkle

This sounds a very much easier question than the last, but we are not yet quite certain of the answer. Of course, you know that it is stars that twinkle, and not the other wonderful things looking like stars, which are called planets, and which, like the earth, belong to the sun's family.

The planets shine by the light of the sun, which they throw back, or reflect, from themselves, as the moon does, and, like the moon, they shine steadily. But the light of the stars is made by themselves, and comes over immense distances to us, so long that the light by which we see the nearest star left it about four years ago.

It is likely that this light interferes with itself as it comes, so that it seems to come in little beats, and people who have studied this think that it is much the same as what sometimes happens with the piano or an organ when the sound seems to get louder, and then less loud, backwards and forewards. In the study of sound this is called a "beat," and it is probable that the twinkling of the stars is really the same kind of thing. It may be that the air has something to do with disturbing the light, and that perhaps starlight is more affected by the air than the sunlight by which we see the moon and the planets.

How a stone is made

Stones are really pieces of broken rock. By the side of the road you can see stones being made with a hammer. These are sharp, as they have been rudely broken.

But rocks are broken up in many other ways. Even the life in the soil on a cliff, for instance, may gradually break up the surface of the rock. If the pieces rub against each other, and are open to the wind and the rain, then they get rounded and dull; but if you take many of these stones and break them, you will find the unchanged rock inside them, often beautifully smooth and bright. There are other kinds of stones which are quite soft. Those we have been speaking of are made of real rock which long ages ago was made under the action of great heat. But you may pick up sometimes a soft stone which you can quite easily rub away—a piece of soft sandstone, which is really very much the same as the sand on the seashore.

Is the matter in earth and air always changing places?

There is a ceaseless circulation going on between the surface of the land and the water, and the bottom layers of the ocean of air which covers them both. Wherever water is, for instance, it is often being sucked up in the form of a gas into the air, of which it then forms part; while, on the other hand, water vapor from the air often passes from it to the earth—as, for instance, in the form of dew. Then the gases of the air, especially oxygen and carbonic acid, are ceaselessly passing between it and the bodies of all the living creatures on the earth; then, from moment to moment, various gases are either leaving the air to be dissolved in the ocean, or are leaving the ocean to join the air.

If we could, it would be well for us if we could mark an atom of oxygen, and watch it for a year or two; and see all the amazing things it does: passing in and out of the bodies of living creatures, in and out of the earth, in and out of the ocean. Then, if we remembered that all the other atoms of oxygen and of other things, too, were doing the same kind of thing, we should begin to understand how wonderfully alive, the whole world is. Perhaps the whole world, indeed, is really alive!

What keeps the stars in their places

The stars are not kept in position, but are all in movement, and sometimes the stars do fall on to one another, we now believe. Astronomers now think that they can find in the heavens two great streams, to one or other of which all the stars belong; and these two streams of stars are moving through and past each other in opposite directions.

No one has any idea at all how this process started, nor what the results of it will be, but at any rate we are quite certain that there is no such thing as what for so long has been called a fixed star, anywhere. Some people have thought that there may be a center somewhere, which all the stars move round, but we cannot find any proof that this is really so.

Why every cloud has a silver lining

The reason is simply that at its edge the cloud is thinner, and much more light can get through it, and that gives it its silver lining. Some clouds, however, are very thin, just like a sheet of tissue-paper in the sky, and we can scarcely notice a silver lining to them. Of course, if we went up in a balloon, above an ordinary cloud which seemed to have a silver lining to us when we were on the earth, we should see the whole cloud bright because the sun would be shining upon it, and it would throw back or reflect the sun's light to our eyes. This is true of the darkest and blackest clouds all through the daytime. The sun is always shining, and the darkest cloud has a bright side.

The trouble for us is that we see the dark side, but we ought to know and remember that the bright side is there. Of course, as we see, all this may have a meaning that applies to the troubles of life, big and little. That is why people remind us that every cloud has a silver lining. But it is even better than that, for every cloud has a silver side just as bright as the other is dark. Some people's minds are always like our eyes in a balloon. They seem to see every cloud on its silver lighted side. These are the kind of people that it is good to live with.

Why all the worlds are round

It is true that all the worlds are round, or very nearly so, and that, if they are not quite round, there is a reason. The earth, for instance, is not quite round, but bulges a little at the equator, simply because it revolves so quickly that it gets a little out of shape. There is something special about roundness, for not only are all the worlds round, but a thing like a drop of water tries to make itself as round as it can; and if you drop melted lead from a height you get round shot. The reason is that in all these cases you have some force trying to pull all the parts of the world or of the drop towards each other. That shape is the sphere, or a round ball.

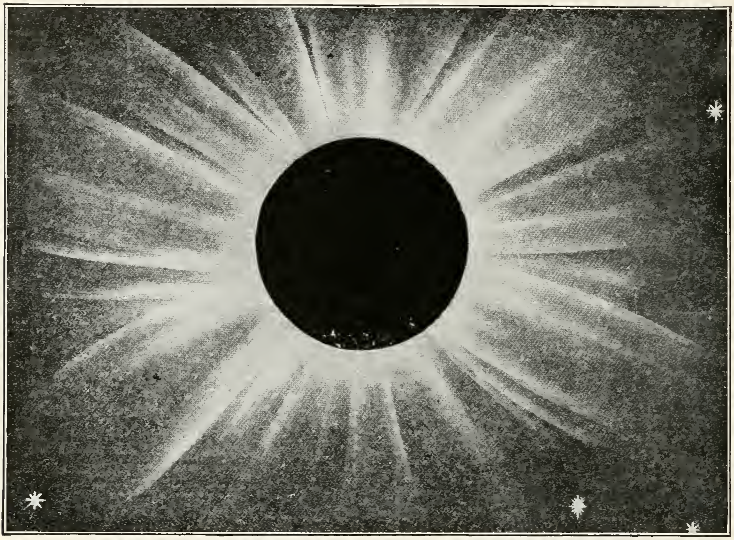
What makes the shadows that go up and down hills

The shadows that we see crossing the face of the hills are the shadows of clouds. They can be seen passing over the sea, too, or running across the field of play when you watch a game of baseball. They are best seen when there are small clouds quickly moving, and with well-marked edges, passing across the sun, as it seems to us, on a bright day. Sometimes they move more quickly than at other times. This depends partly on the wind, which varies very much in speed, and on the height of the clouds.

THE BIGGEST SHADOW THAT WE CAN SEE

There is one great shadow, thousands of times bigger than any other, which men have noticed at times in all ages, and which has often made them very much afraid. This is the shadow of the earth itself, and it is thrown upon the moon. It sometimes happens that the earth gets in the way of the light from the sun which would fall upon the moon if the earth were not there. And so we get what we call an eclipse of the moon. As we watch the moon, we can see a round shadow beginning to creep across it.

Sometimes it passes over only part of the moon; sometimes it covers the whole moon for a little while, and we call that a total eclipse of the moon. When we watch this shadow—one does not even need a glass to see it with—it is easy to see that the shadow is curved. It is the shadow of a round thing, and this is one of the proofs that the earth is really round. In olden days men used to be very much afraid of eclipses of the moon and of the sun. They used to think that it was a warning of something terrible about to happen. But now we know that an eclipse of the moon is nothing more than just the throwing of a great shadow upon the moon's face, and that is the shadow of the earth, by far the greatest shadow that anyone can ever see.



THE SHADOW OF THE MOON BLOTTING OUT THE FACE OF THE SUN

This is one of the most impressive sights that men have ever seen—the moon passing across the face of the sun. It happens sometimes that the moon gets directly in the way of the sunlight which would fall upon the earth if the moon were not there, and we call this an eclipse, or covering up, of the sun.

WHAT MAKES AN ECLIPSE OF THE SUN

The kind of eclipse that used to frighten people most is an eclipse of the sun. It does not often happen that the sun is totally eclipsed, but when this does happen on a bright day, the effect is wonderful. It suddenly becomes dark, until it is like night; it turns cold; the dew falls; the birds go to roost; the flowers go to sleep; all this, perhaps, in the middle of the day, and with not a cloud in the sky. Then, just as suddenly the daylight returns. An eclipse of the sun is not due to a shadow, but happens when the moon gets between the earth and the sun, and we see the moon pass across the sun.

This happens quite often, but it is not often that the moon passes across in such a way that, for a little while, it exactly fits over the sun, and cuts off all the light. Those are the startling times. We know beforehand when they are to happen, and to what parts of the world we must go to see them, and exactly how long the period of real darkness will last. Great preparations are made, and men go with telescopes and cameras and all sorts of other instruments, perhaps to Greenland, perhaps to some island in the Pacific Ocean, just for the sake of the forty seconds, or perhaps it may be as much as four minutes, during which the moon will exactly fit over the face of the sun. For we can see things and learn things about the sun during those few seconds as we never can at any other time.

THE MILKY WAY

Students of the stars think that the Milky Way is the boundary of our world of stars. It is a complete closed circle where the sky is crammed with stars; yet in places there are gaps where we can see through beyond into nothing. We can begin to measure the diameter of this great circle. Our own sun and system seem to be somewhere near the center of it, and a very remarkable thing about the sun, and therefore about us, seems to be that it is very much alone in the world of stars. The sun has no near star neighbor, while most of the other stars are much more neighborly, especially throughout the whole circle of the Milky Way. We cannot tell at all whether the whole Milky Way is moving through space, and we do not know whether it is moving round on itself; but we can study and photograph it now, and long years afterwards our successors may compare our photographs with what they then see, and may be able to learn about these things.

Look closely at the Milky Way on a bright night, and you will see that it is made of many stars, only they seem so closely packed together that their light is all blended, looking like a thin cloud or a milky streak spread across the sky. If you use an opera-glass or a telescope, you see the separate stars more clearly, and if you take a photograph through a telescope—which is quite an easy thing to do—you find that the stars of the Milky Way are to be counted not in thousands, or even in hundreds of thousands, but actually by the million.

From any one part of the earth we can see only about half of the Milky Way, but this great streak of stars really forms a mighty circle, the different parts of which can be seen from different parts of the earth. The sun and the earth and other planets with it lie somewhere not very far from the center of this great circle. Now every one of these millions of stars is a sun like ours, only some are smaller than our sun, and many are larger. Any or all of these suns, for all we know, may have one or many planets circling round it, just as the earth moves round the sun. We cannot see these planets, for they must be too small, and without any light of their own, just as the earth is. So that if we were to allow only two or three planets to every star or sun that makes up the Milky Way, that would mean hundreds of millions of worlds of varying sizes.

What the streaks of light are that sometimes shoot across the sky

These are called shooting stars. Of course, they are not stars, but quite small things, often just like stones, though some of them are made of iron. They look bright merely because, as they rush through the air, they get very hot. The smaller ones, no doubt, get so hot that as they pass through the air they burn all away, just as a candle does, and so they never reach the earth at all. But larger ones actually reach the earth, sometimes making big holes where they fall. You may have seen such things in museums, and you can look upon few things more interesting if you think of their history, for in the beginning these things did not belong to the earth at all; only they were rushing through space, many parts of which contain large numbers of things like pebbles, and they were caught by the air of the earth and the earth's gravitation.

Many of these meteorites, as they are called, are believed to have once been part of the bright things called comets. Sometimes an accident seems to happen to a comet and breaks it up, and in the path where this comet used to travel round the sun there is, instead, a great shoal of meteorites. When the earth, in her path, happens to cross the path of the meteorites, many of them will be caught, especially if it be just at the time when the thickest part of the shoal is passing. So we know the times of the year and the special years when we may expect to see a large number of streaks of light in the sky at night. The best showers of shooting stars are usually seen in November, when the earth crosses the path of a shoal of meteorites called the Leonids.

Is the earth hollow inside?

Though no one has ever seen, or ever can see, the inside of the earth, we are certain that the answer to this question is "No." We know that the earth has a solid crust, very thin, and very apt to crack and "buckle," producing such things as mountain chains in consequence, and we can prove that this crust must be utterly different from what lies underneath it. Now one of the many ways in which we can learn about the inside of the earth is by weighing the earth, and noting its weight in comparison with its size. This teaches us what the density or denseness is of the stuff that makes the earth, and the result is a conclusive answer to the question.

If you have a small ball which weighs tremendously heavy — far heavier in proportion to its size than any ball you play with—you would not suspect it of being hollow, but rather you would wonder how it came to be so tightly packed and squeezed together. That is the case with the ball we call the earth. Its denseness is very high, indeed, and the material in it is packed together with more tightness than we can imagine. We have just scratched the surface of the earth, and already in going down even such a short distance we find the density increasing, as it must, if we think of the weight that lies over us at the bottom of a mine.

What causes an earthquake

The first reason that probably accounts for all earthquakes is simply that the earth is shrinking as it gradually loses the heat from its surface. We know that the earth has a thin crust, which is comparatively cool, and hot inside. The crust rests upon the inside of the earth, and as the inside shrinks it is bound to leave parts of the crust unsupported, so that they are apt to sink or crack. This will happen especially where the crust of the earth is thinner and more liable to crack than in other places. It is very common in Japan, for instance, and very rare in the Mississippi Valley.

But when an earthquake happens at any part of the earth, it starts a wave of disturbance that travels right over the earth, and can be detected anywhere by means of the seismograph. Then, if we notice the time when the wave reached a place, and find out what the time was when it started, we can learn how quickly the earth-wave travels. But sometimes no one knows where the wave started, and then very often we can guess that it started under the sea; for earthquakes may start in the earth's crust where it forms the beds of great oceans as well as anywhere else. And so there may be earthquakes at the bottom of the sea.

How the planets got their names

The names of most of the planets are very old indeed, and they were given to them for interesting reasons worth knowing. Mercury moves very quickly, for it is so near the sun that it would be drawn in unless it moved quickly, and its name—Mercury—is after the "messenger of the gods," whom the Greeks and Romans invented and believed in. Then Venus is very beautiful and gets its name from Venus, the supposed goddess of beauty. Mars is reddish and so suggests blood, and was therefore called Mars, after the god of war. Jupiter is the biggest of the planets, and is called after Jupiter or Jove, the greatest of the gods whom people believed in long ago.

Then, to take one more instance of the way in which the planets are named, there is Uranus, now so named, like the others, after an ancient god. It was discovered by a German, William Herschel, who lived in England, and he wanted to call it Georgium, after the King of England. Others wanted to call it Herschel, after the discoverer, which would certainly have been wiser than to name it after a king who had nothing at all to do with it; but finally it was agreed to give it an old name like the others.

As for Earth, the good mother of us all, the ancients called her Ge, and so now we call the study of the earth ge-ology; while what we call the moon they called Luna. Hence, we have the word lunatic, because in ancient times it was thought that when a man lost his mind, it was through the influence of the moon.

Who gave the stars their names

Nowadays we know an enormous number of stars—about 100,000,000—and the smaller ones (or rather the fainter ones, for they may only seem small because they are distant) simply get numbers or letters, for all the world like automobiles, in order to identify them. But the brightest stars have been known for many ages, certainly not less than 10,000 years, and the origin of their names is lost, like the names of the men who named them.

Some of these names we call Latin and Greek and Arabic, but certainly many of them are far older than the Romans or the Greeks or the Arabian astronomers, and they got the names from those who went before them, just as we have got the names from them. A star with a specially interesting name is the Polar star, which gives us the direction of the north. No one can say how many millions and millions of sailors' eyes, throughout thousands of past years, have been gratefully and often anxiously fixed upon that star, by which they could steer their way home across the path-less sea. But for all those sailors that star has doubtless been known by whatever word stood for north, in whatever language the sailors spoke. The names of great stars like Aldebaran and Sirius must be older than any human record.

Where the day begins

The world is full of mysteries and of wonders, and there is no need for us to puzzle ourselves by making any that do not really exist. We could quite easily make all sorts of puzzles about time and the way in which it is reckoned; but we must understand that these puzzles are not real, but are made entirely by ourselves—not by Nature.

The real fact is quite simple. The sun goes on shining all the time, you know—it is well to remember that "the sun is always shining somewhere" —and the earth is spinning all the time. So the sun is always seeming to rise somewhere, because at some place or other the earth is just spinning round, so as to face it, and the sun is always seeming to set somewhere, because at some place or other the earth is just spinning away from the sun. That is simple.

And, of course, whatever we call now, whether we call it six o'clock or twelve o'clock, this now is now everywhere. The present moment is the present moment here and on the farthest star. Only when just opposite the sun we call that midday, whereas the people on the other side of the world are then away from the sun, and call it midnight; but this present moment of ours is their present, too, of course, and the difference is merely a difference of name to indicate that now we are opposite the sun, and they are away from it. It would be foolish for us to make a mystery where none really exists, or to forget that now must be now everywhere.

But, simply because the earth goes on spinning, and the sun is always shining, the day is dawning somewhere always, and really, therefore, the answer to the question, "Where does the day begin?" is that the day is always beginning somewhere.

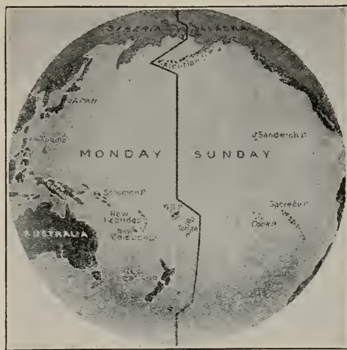
Two days at once

Since people live in different parts of the world, what we call night (when it is our night) will be someone else's day, and our midnight, when a new day begins for us, as we reckon, will not be the midnight of other people in other parts of the world, so that what we call Monday they may call Tuesday, yet we and they are both talking about the same moment!

Now, it would be very inconvenient if all the different parts of the world east or west of each other persisted in talking of time as if they were the only people on the earth, and as if their midnight must be everybody's midnight—which it is not. So we reckon by two sorts of time. One is local time—the time reckoned by what is happening at the particular place whose time it is; the other is standard time, which we agree upon, so that we can catch trains, and so on, just as if midnight in one place were midnight everywhere. Up to 1883 people often missed trains through this difficulty, and then "standard time" was invented.

Where the day changes

A clock shows that it is never midnight at the same time at any two places which are not the same distance from the line passing through Greenwich—or, indeed, from any such line, only we take Greenwich for convenience. Therefore it may be one day at one place, and the day before or the day after at another. In order that we shall not get more mixed than we can help—and we cannot help getting rather mixed since we don't all live on the same line, and the earth will keep on turning!—we have agreed that we shall take a line exactly on the other side of the earth from the Greenwich line, and this we call the "date line." What is called Sunday on one side of this line is Monday on the other side. If the "date line" passed through a country or through a city, this would be inconvenient. People living on opposite sides of the same street might have different days for Sunday. They would have no doubt that now is now everywhere, but they would call now by different names. Fortunately, however, the date line scarcely touches any land at all, and the little it does touch is very unimportant. The line passes across the ocean.



The international date line, with Sunday on one side and Monday on the other

THE CHILDREN'S "WHYS" AND "HOWS"

Why we count in tens

YOU may well ask why we count in tens, for it would be much more convenient if we counted in twelves—if we had a duodecimal system of counting in twelves instead of a decimal system of counting in tens. If we should invent two extra single figures for ten and eleven, and then write ten to mean twelve, and eleven to mean thirteen, 100 to mean 144 (twelve times twelve instead of ten times ten), and so on.

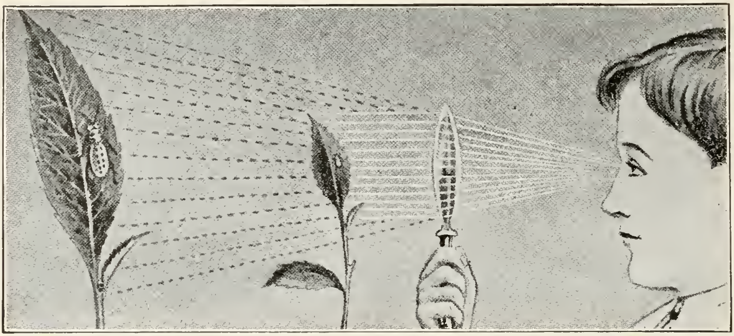
Perhaps we will do this some day; and the reason is that, while ten can be evenly divided only by two figures, two and five, twelve can be evenly divided by four figures. Thus, for many purposes it would be better to count in twelves, and, indeed, we often do so when we can, as, for instance, by making twelve inches to the foot instead of ten. This would also fit in nicely with the number of months in the year. But we count in tens still, as a rule, and we shall doubtless do so for many a long day yet, simply because our ancestors have always done so.

If you think how you sometimes used to reckon when you started arithmetic, you will guess the simple reason why. It is because we have ten fingers. When we count on our fingers, as children do, and as the first men did, it is natural to make a fresh start after ten, because then we go back again to the finger we began with. So all over the world, we find men counting by tens—using a decimal system—just because men and women everywhere have ten fingers.

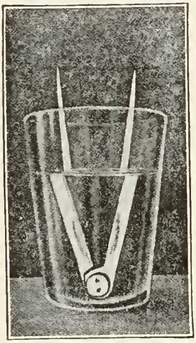
Why a stone sinks

The stone sinks because it is heavier, or denser, than an amount of water occupying the same amount of room; and the water floats on top of the stone just as the stick floats on top of the water. It all depends upon the great law of the pull, or attraction, of the earth for everything outside it, and the heavier the thing is, the stronger the pull. A lump of iron sinks in just the same way.

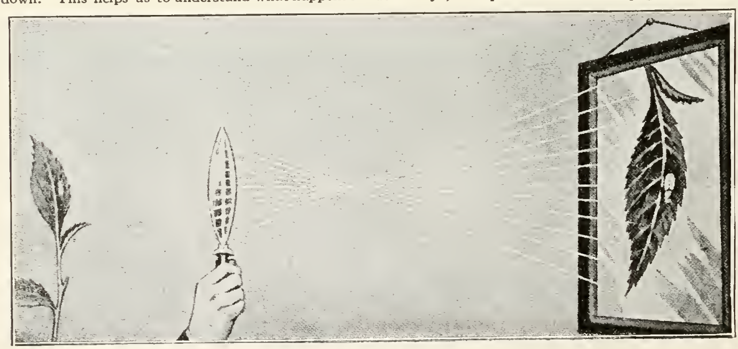
HOW A MAGNIFYING GLASS MAKES THINGS BIGGER



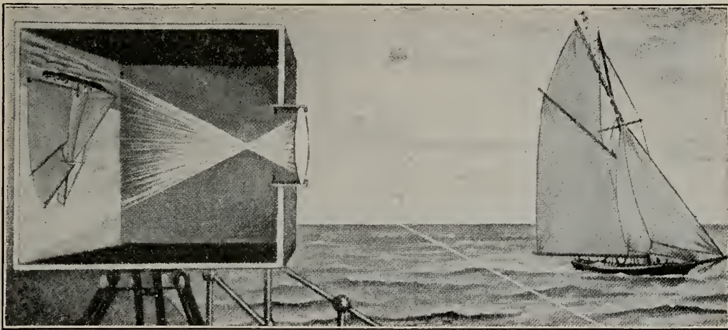
These pictures how us how a magnifying glass makes things appear larger than they really are. What happens when we look at, say, a leaf, is that rays of light are thrown off by the leaf and brought together to our eyes. When we use a magnifying glass the rays of light pass through the glass and bend—as a stick



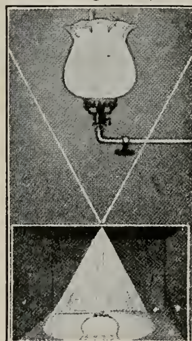
appears to bend if you put it in water, or as the pair of compasses seems to bend in the glass of water shown on this page. When the rays of light reach the eye, the eye imagines that they have come in straight lines, and it appears to the eye that the light comes in lines as shown by the dots in this picture. What we really see are rays of light. These rays not being able to go straight through a magnifying glass as if it were a piece of ordinary glass, are bent in passing through the glass, and what happens then is as if the eye having collected all these rays to a point, throws them out again in straight, sloping lines, at the end of which we see the image, looking much bigger than it really is. So that what we see through a magnifying glass is not the actual leaf but the rays of light thrown off by the leaf, first bent by the glass and then straightened out again so as to appear to cover a much bigger space. A curious thing happens if the rays of light are allowed to continue beyond the eye instead of being focused by the eye. We can do this with the aid of a microscope, as shown in the bottom picture. In this case we see the leaf upside down. This is because the rays of light meet, and then as the rays must go straight, the line of light coming from the top of the leaf goes down while the line coming from the bottom of the leaf goes up. In the top picture the meeting or focusing of the lines of light takes place inside the eye, but in the picture below we see the rays focused through the glass instead of inside the eye, and we see them, therefore, continuing, until they are reflected in the looking glass, where we see the enlarged picture upside down. This helps us to understand what happens inside the eye, as explained on the next page.

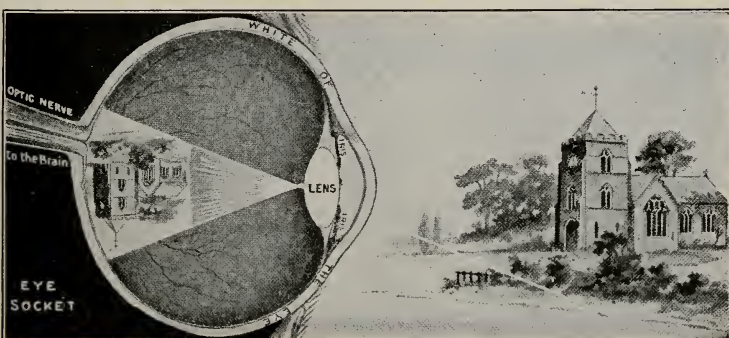


HOW THE CAMERA TAKES YOUR PHOTOGRAPH



These pictures show us how a camera takes a picture, why it takes the picture upside down and also how the eye is like a camera in this way. The boat in this picture gives off rays of light which strike in all directions. Some of these rays go out towards the camera, and as light always travels in straight lines, never crooked ones, all the rays that can be seen from the lens of the camera travel straight up or down towards the lens. Inside the lens they continue traveling in the same direction and at last they meet and cross so that the lines of light given off by the top of the boat strike the bottom of the photographic plate and the lines given off by the bottom of the boat strike the top of the plate. The small picture on this page shows a way in which any boy or girl can find out how the lines of light cross so as to make an image upside down. Take a white cardboard box without the lid and prick in one side a small hole with a pin Hold the box, say, under a gas jet so that the gas will reflect through the hole. The hole will then act as a focus of the rays which will enter the box through the hole and cross, so that the inside of the box where they fall will reflect the gas jet, which will be upside down. The bottom picture shows us that the eye acts in the same way as the camera but a very wonderful thing happens in the eye, that no man quite understands. When the photographer finds that his picture is upside down he turns the plate the other way and everything is right. But what wonderful thing is it that turns the picture printed inside the eye the right way up? The rays of light stamp themselves upon the retina of the eye as seen in this picture and the nerve of the eye carries them to the brain. What happens there nobody knows but when the brain brings together these rays of light so as to make a clear picture, the picture is the right way up. The picture is printed on the retina of the eye upside down, but our brain puts it right in the millionth part of the twinkling of an eye, and this is, perhaps, as great a miracle as anything that ever happened.





Why a wheel stops

One of the reasons why a wheel stops when it has once been started is the resistance of the air. But wheels also stop through another kind of resistance, which is called friction. The wheel of a bicycle, for instance, travels round and round on something in the center of it, which we call the axle, and as the wheel rubs against the axle it is made to go slower. If you put your finger on your arm and rub it along your skin and press a little, you can see how you are opposed by friction; but if you put some oil on the tip of your finger first, the finger will slide along your arm quite easily, because the oil lessens the friction.

For exactly the same reason you have to oil the bearings of a bicycle. Perhaps you know that a special way has been found in which to lessen the friction of a bicycle, so that, after you stop pedaling, the wheels will go on running much farther than they otherwise would. A number of tiny steel balls are put between the axle and the wheel, so that the wheel really runs on these little balls. This is what is called "ball bearings," and every bicycle has them, both for the wheels and for the pedals.

Could a top spin forever?

Friction also helps to stop a top, but if you spin the top on a perfectly smooth plate, so that there is very little friction, it will spin much longer; and if you could spin the top on a smooth plate inside something from which you had taken away all the air, it would not be difficult to get the top to spin for hours, because things which have once started moving go on moving until something stops them. If the top could be spun where there is no air at all, and nothing happened to hinder the spinning, the top would certainly go on forever. The earth is like a great wheel or top spinning round and round in space, but, as space is almost empty, and as the earth's air is part of the earth and goes round with it, and as the earth is not spinning on anything, as a top spins on a plate, the earth scarcely slows down at all throughout the ages.

How fast a wheel can go round

You might think that if you applied sufficient force to a wheel—say, the wheel of some kind of engine that was driving something—it would go round faster and faster, and there need be no limit at all to the speed at which it went round. But that is not true, and sometimes when men forget it and make wheels go round too fast, accidents happen. If you take an umbrella that has been out in the rain, and twirl it round very gently and slowly, the drops of rain will hold on to the umbrella tight enough to go round with it, but directly you spin the umbrella a little faster, the drops of rain, as you know, fly off from the umbrella. As long as the umbrella went round slowly, the force of sticking, or cohesion, as it is called, was sufficient to make the drops stick to the umbrella, but when the umbrella went round a little faster, the force of cohesion could not keep the drops sticking to the umbrella, and so off they fly. But now, after all, it is nothing but cohesion that makes the parts of a wheel stick to each other, and if the wheel went round quickly enough, this cohesion would not be strong enough to hold the wheel together, any more than it is strong enough to hold the drops to the umbrella if spun quickly.

Could a wheel fly off an engine

Sometimes when an engine has been running too quickly, a great wheel, perhaps made of heavy steel, has flown to pieces. These pieces have gone flying out just as the drops do from a spun umbrella, and sometimes these have done terrible damage. This applies to everything that spins—the earth, or a wheel, or a top. There is a limit to the speed at which it can spin without flying to pieces, because there is a limit to the power of cohesion, or holding together, and directly that limit is passed, the pieces of the wheel, or the top, or the earth—if the earth were set spinning too quickly—must fly away. For everything that is moving tries to move in a straight line, and the reason why a wheel can spin at all is that the parts of it move in circles instead of in straight lines, because they are held by cohesion; but if cohesion is not strong enough, all parts of the wheel, like the drops on the umbrella, will start moving in straight lines instead of in circles, and the wheel will fly to pieces.

What makes an automobile go

The mystery of the automobile is, of course, only the old question of using natural forces for power. In nearly all automobiles it is a gas that makes them move. In one way or another this gas is made in the engine of the car or is sent into it, and, as this gas is made under pressure, its atoms fly about in all directions, and so press upon that part of the engine which is connected with the wheels. In most automobiles gasoline is burned with air, which is admitted to the inside of the engine, and the gases which are produced by this burning make the car move. Gasoline is really a vegetable product, and has in it the power which poured upon the earth from the sun ages ago. It is really the sun, then, that makes the car move; not the sunlight of today, but the stored-up sunlight of long ages ago.

In steam automobiles the power is produced as it is in a railway engine or a steamboat. Something is burned—generally gasoline—and so boils water, and it is the water-vapor or gas that acts on the engine in this case, just as the gases made by the burning of the gasoline act upon the engine in the commoner kind of automobiles. Electricity is used in ordinary automobiles to set the gasoline burning. Each time the spark passes, a little gasoline is burned, and it is this burning that makes the noise that we hear, or part of it. The car is made to go, therefore, by a very large number of little gas explosions.

Why soap takes out the dirt

The answer to this question has been a great deal argued by chemists, and it is a very important thing, for cleanliness is necessary, and enormous quantities of soap have to be used, and it is well that we should know how soap does its work, so that we can make the soap that works best.

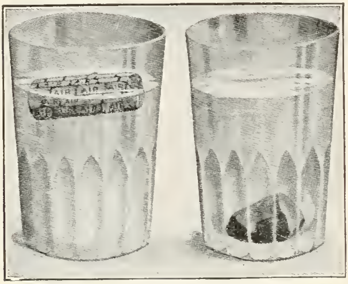
Now it is fat or oil that especially makes things dirty. If only we can melt or get rid of the oil on things, we soon make them clean, and the real use of soap is that it disposes of oil. It does this in at least two ways. Most soaps have in them a great deal of alkali. This alkali dissolves the oil that gathers on things, and makes them clean.

But soap takes the dirt from things in another way, as we know when we use soaps that have no alkali in them at all. It has the power of breaking up oil into a number of tiny little drops, which are easily washed away, together with all the dirt that the oil has collected.

A collection of tiny drops of oil, held in some other fluid, is called an emulsion. Water alone will not form an emulsion of any oil, because oil and water will not mix. That is the reason why we cannot wash well with water alone. But when water has soap dissolved in it, it is able to make an emulsion of the oil on anything we are washing, and so makes it clean.

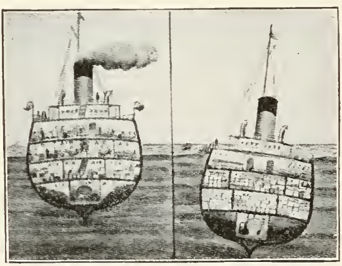
WHY DOES A STICK FLOAT?

We must remember that the earth is all the time trying to pull everything to itself; it pulls us, it pulls the air, it pulls a balloon, it pulls the moon. Now, the heavier the thing is the more it is pulled, and water is heavier than a stick. This does not mean that all the water in a pond is heavier than a stick, because we know that. But it means that if you have a cup and filled it with water, and had another cup the same size and filled it with stick, the cup with the water would be heavier—that is to say, in a fixed amount of space you can pack a greater weight of water than of wood. That is what we mean when we say that the water is heavier than the stick.



WHY WOOD FLOATS AND IRON SINKS

Wood floats because it is full of tiny quantities of air, and so is lighter, or less dense, than the water. A stone, or a lump of iron, has no air in it; it is denser than the water, and therefore it sinks. An iron ship floats because it is hollow and full of air, so that as a whole it is lighter than the water. If we filled it up solid with iron or stone, or if it cracked and so let the air escape from it and the water come in, it would sink, as shown in the second of these pictures.



WHY AN IRON SHIP FLOATS

Of course, a pound of water is the same as a pound of stick, and you do not need to answer the question—Which is the heavier, a pound of feathers or a pound of lead? They both weigh the same, only the lead takes up less room, and so we say that lead is heavier than feathers, though a pound of lead weighs the same as a pound of feathers. The proper name for a heavy thing is dense, and, whenever it is possible, the earth always pulls the denser things further down, and the less dense things float on the top of it. That is why the stick floats; that is why the cold air is found nearest the floor, because cold air is heavier, or denser, than warm air, and the warm air floats on the top of it as the stick floats on water.

WHY AN IRON SHIP FLOATS

Men used to think that a ship had to be made of wood in order to float, because wood floats and iron sinks. But now all big ships are built of iron. Why do they not sink like a stone or an anvil? It is because of their shape. When they are hollowed out the whole space they occupy is filled with air, which makes the ship, as a whole, lighter than water, and so it floats. You can even put things into it, but the more you put in, the deeper your ship rides in the water. You can store iron in it, but if you packed it full of iron, or anything heavier than water, it would sink.

One brave man fought for years for the lives of sailors, and at last got a law made that a line should be painted outside the hulls of ships, and that the ships must not be packed so heavily as to sink that line below the surface of the water. Like everyone who does anything worth doing, he was laughed at, but his name will always be remembered, and that line, which protects sailors, will always be called Plimsoll's line, in his memory.

What a vacuum is

Vacuum is simply a Latin adjective meaning empty, and we have an English word, vacuous, which has the same meaning, and which we sometimes apply to the expression of a person's face when it seems to mean nothing—to be empty of meaning. In the study of Nature we often talk about vacuum, meaning by that an empty space. It is always necessary to remember that there is really no such thing as empty space, for what we call the ether is everywhere.

But when we speak of a vacuum we are leaving the ether out of account, and are simply thinking of gases, such as the air. We take such a thing as a globe of glass, which cannot collapse when the air is sucked out of it and we attach a pump to it, so as to suck out of it all the air we can. When we have done so, we call the space inside the glass globe a vacuum. As a matter of fact, we can never get a real vacuum, but only a space which contains comparatively little air. No one has ever made, or ever will make, a perfect vacuum.

How a mackintosh keeps us dry

A mackintosh keeps us dry because it is made of a material which water cannot get through. Our ordinary clothes are full of tiny little holes, or pores, and so we call them porous. The water runs into these little holes. and so will make our clothes wet, just exactly as it runs into a sponge, which is also full of holes, or pores—only these are so big that we can see them. But if you take a thing like a piece of india-rubber, you find that water cannot get through it because there are no holes in it to let the water through; or you can take a piece of ordinary cloth, which is porous, like a sponge, and then, if you melt india-rubber and put the cloth in it, the rubber will fill up the holes in the cloth, making it waterproof.

The name of the man who discovered how to do this was Mr. MacIntosh, and that is why many kinds of waterproof coats are called mackintoshes now. For no particular reason we have put a "k" into the word. Now, there is another kind of material which also keeps water out, or, at least, in its natural state it keeps water out, but we cut it up and put it into bottles and use it to keep water and medicine in. There is a special kind of tree which makes this cork, but really all trees have a layer of cork inside the bark, and this makes them waterproof. India-rubber is also obtained from trees.

And so, when we wear a mackintosh, we first of all take something from the coat of a sheep to make woollen cloth, and then we take something from the world of plants in order to make the cloth waterproof.

Why ammonia cleanses things

Ammonia is really a gas, but like other gases it can be dissolved in water and is more soluble in water than almost any other gas. The solution of ammonia gas in water is what we usually call ammonia, and it is largely used for cleansing things. Indeed. people add what is called, not quite correctly, "liquid ammonia," to the water of their bath, for they find that it helps to make them clean. "Liquid ammonia" is not a correct name, because what we call that is really water containing a lot of ammonia gas.

Ammonia cleanses many things far better than even strong soft soap, but it is so powerful that we cannot use it for everything. The reason why ammonia is such a splendid cleanser is that it is an alkali, and so dissolves fats and oils, as the alkalies in ordinary soap do. But ammonia is different from all other alkalies, because it is really a gas, and the great fact about a gas is that, if it gets "half a chance," it goes everywhere. Ammonia is thus the most searching of cleansers.

Why houses are not made of iron

We are doing just what men did long ago when they passed from the "Stone Age," in which they used stone for knives and weapons, to the "Age of Metals," when they used brcnze and copper and iron. We may say we are passing from the Stone Age to the Age of Metals in buildings.

Of course, in the case of a bridge, we simply use steel and do not think it necessary to do more. One of the most wonderful, though not the most beautiful, bridges in the world is the Brooklyn Bridge, which is made of steel. When it comes to ordinary buildings, however, the builder makes his building of steel; but we are not accustomed to buildings made simply of steel, and they would look very unusual to our eyes; so after he has made the steel skeleton of his house, or whatever it is, he covers it all up with stone, so as to make it look as if it were really the stone that was holding it up; yet really you might take all the stone away, and it would stand as before. The real reason for not making steel exposure is that it is such a good conductor of heat that we would roast, whereas stone or brick is a poor conductor.

How a bar stays in its place

All solid things have cohesion, and we can almost imagine the tiny parts of which they are made holding on to each other, as if they had little arms or hooks. That is why things can be solid; that is why they can have a shape and keep it. You see, the earth is so enormous, compared with anything that we can make or move, that, if there were nothing else to act against the power of the earth's gravitation, everything would crumble down quite flat, so that all the stuff in it might be pulled as near as possible to the center of the earth.

A bar holds together, because, though gravitation is always acting, and is very powerful, cohesion is very powerful too. You know, for instance, the horizontal bar in the gymnasium? How does this stand? How does it come to stand so firm that it will support your weight? The answer is that, though the earth is pullling it down all the time, the earth's pull is balanced by the cohesion of the bar. If you tried to make the bar of something that has very little cohesion like sand—well, you might try for a very long time before you succeeded! Of course, it is true that gravitation acts between everything and everything else. It acts, for instance, between the tiny parts of which the bar is made, or of which the bar of sand—if such there could be—is made.

What the first buildings were like

The first devices men ever lived in began by not being buildings at all; they were just holes or caves in the earth. We have found some of these caves with bones and teeth and other things which tell us what these men ate long ago. The first attempt that man made to build was simply to make the caves that he found rather bigger and more convenient; and so he scooped them out and made them deeper, and often he scooped away much of the roof so as to make the cave higher, and let him stand and walk upright in it. And when at last man began to build for himself, he made huts, such as many peoples live in even nowadays, like the Eskimos. And these huts are really very like caves if you come to think of it.

WHO INVENTED ARCHES FOR BUILDINGS

One of the remarkable things about the great buildings of Greece is that they do not have arches. Their buildings, indeed, were in principle the same as you can make with toy bricks. Now, it is a curious thing that somehow or other, though the Greeks learned so much from the Egyptians as regards science and art and many other things, they did not know about the arch. Yet, even in very early Egyptian buildings, we find various kinds of arches, including even the pointed arch which you must have seen in many churches. There are two kinds of arches—one built up from the two sides, and then at the very top of the arch there is put in last, a stone called the keystone, because it keys, or rather locks the two sides of the arch together. People who study buildings say that the kind of arch they call Gothic does not have a keystone, the two sides meeting in a straight up and down line.

WHO THE BEST BUILDERS WERE

Now, you know that the Romans came after the Greeks, and that nearly everything they knew and could do they learned from the Greeks. Indeed, there was a great deal which the Greeks knew and the Romans forgot. The Romans did not build beautifully as the Greeks. There never was any building in Rome so lovely as the Parthenon. But one thing the Romans had which the Greeks had not, and that was the arch. No one appears to know whether some Roman found out all by himself how to make an arch, or whether they found arches in Egypt or somewhere else; but, at any rate, the Romans had the secret of the arch, and they seem to have been very proud of it, and used it whenever they could.

They were very fond of building what they called triumphal arches in honor of some great soldier or some great event, and you will see such arches in Rome and many parts of Italy.

In our own times we have made a great discovery as regards buildings. You know that instead of building ships of wood we build them of iron and steel. Well, we do the same thing now in building; instead of stone we use steel.

WHICH TRAVELS QUICKER—HEAT OR COLD?

Complete cold, if we could get it, would only be complete absence of heat; and what we ordinarily call cold is simply less heat than in something else with which we are comparing it. When a thing gets cold, it really gets less hot. So we cannot speak of cold traveling, unless we mean that it is a cold wind that is traveling, or cold water traveling through hot water, as when you run cold water into a hot

A GREAT LINE OF ARCHES BUILT BY THE ROMANS, WHO WERE FOND OF ARCHES IN BUILDING bath. But we can say how fast heat travels, if by that we mean the rays of heat or radiant heat that we feel near a fire or a light. This kind of heat is really the same as light, and it travels at exactly the same speed, which you know. But cold travels at no speed, for there is no such thing.

What holds a building up

We all know that mortar holds the bricks together; but we must remember that the wise builder always uses the weight of his bricks to make his building strong; and since it is the earth, with its steady pull, that gives bricks, and all other things, their weight, we must not give the mortar all the credit. No bricks and mortar would ever make a strong building if there were not the earth's pull to bind them all together.

Why a stick holds together

Mortar, as you know, "sets hard," like many other things—jelly and water included—if you give them a fair chance. And the power by which it, or paste or glue, holds things together is called cohesion—a word which simply means sticking together. We cannot see what really happens, but cohesion is one of the commonest things in the world. When you move one end of a stick, why does the other end move? Because of cohesion between all the parts of which the stick is made. All the parts of the stick hold together as if drawn to each other by a magnet.

Why we can't make a rope of sand

We can't make a stick or a rope of sand, and you can't build with bricks and sand. The sand has no cohesion, except just the least little bit when it is wet. Have you ever thought why sealing-wax melts when it is heated? The truth is that cohesion is one of the most important things in the world, and that the world itself, indeed, could not exist as it is without cohesion. Everything that we call solid is solid because the tiny parts of which it is made stick or hold together. A piece of sealing-wax, for instance, if it is left alone, is held together by cohesion. It does not spill itself and run all over the table, and if you lift it up by one end the other end comes too. But if you apply heat to the sealing-wax it begins to run—it begins to lose its stickiness, or cohesion. This shows a second state in which anything may be, and this state we call liquid. Running water is liquid.

Why water runs

That is cohesion again; water runs because it has no cohesion, or else very little. While all solids have a great deal of cohesion—without which they could not be solids—liquids have very much less. But all liquids are by no means the same. Liquid water has very much less cohesion than liquid sealing-wax or liquid gum, which, indeed, has so much cohesion, or sticking together, that we appropriately call it "sticky." On the other hand, liquid alcohol or liquid air—did you know that air could be liquid like water?—has very much less cohesion even than liquid water. But there is a third state in which anything may be, and that is the state of a gas—like air in its ordinary state, and like the gas we burn for light. Now, the thing which marks a gas is that it has no cohesion at all—it runs wherever it can. However big the space that it is in, the gas always fills it. It goes under doors, out at chimneys, and out at windows, and so on. It has no cohesion.

Why the smoke of a train goes the other way

When the smoke leaves the funnel of the engine it is really moving forward, like the engine itself, and at exactly the same rate. If we could imagine that the train was moving onwards in nothing, then, since we know that moving things always move on in a straight line at the same speed forever, unless something outside affects them, the smoke would move forward with the train, and would actually pass on in front of it as soon as the driver slowed the train. But the smoke, we know, is really poured into the ocean of air through which the train is pushing its way. The air tends to stop the train, as it tends to stop everything that moves through it, and every engineer knows how important this air-pressure is; but though it retards the train a good deal, it retards the light, hot smoke that is poured into it far more. The question reminds us that the smoke seems to go in the opposite direction to the train; but really it simply moves forward so slowly and for such a little distance that, compared with the train it seems to go the other way.

But if a strong wind is blowing in the same direction as the train—and perhaps this is oftenest seen in the case of the smoke from a ship's funnel —then the smoke is blown forward by the wind far in front of the train or ship. In this case and the last the same principle works, though the results are so different. The principle is that the air affects the smoke more than the train or ship. In one case it holds both back, but it holds the smoke back most; in the other case it blows both forward, but the smoke most.

Why some faces in pictures seem to follow us

You are discerning to have noticed this, and perhaps you have also noticed that in other pictures there are faces which are not looking at us; but no matter where you walk, even though it be in the direction in which they seem to be looking, you will never find the face looking at you. Indeed, faces in pictures are either looking at us, from wherever we look at them, or else they are never looking at us, from wherever we look at them. The same is true of photographs.

The rule is very simple. If the person who was being painted or photographed was looking at the painter or at the camera, then, wherever you stand, he will seem to be looking at you. If he was looking on one side, then, wherever you stand, he will seem to be looking on that side of you. This works very queerly if you have a group of people who were all looking at the camera when they were photographed. If you look at the photograph from one side, they all seem to turn to follow you, and then to turn back if you look at it from the other side. But if they were not looking at the camera, you can never get them to look at you.

How burglars are caught by their finger-prints

You have heard, perhaps, that nowadays burglars wear gloves in order to avoid leaving their finger-marks on a window-pane or anywhere else. The fact is that all men and women differ

These are the marks of men's fingers on things they have touched. Finger-prints like these help the police to catch burglars. No two finger-prints from different people have ever yet been found to be alike.

from each other in little things, and there is nothing in which they differ more certainly than the pattern of the little ridges on their fingers. Two patterns exactly the same from two different people have never yet been found. These patterns cannot change, for they are formed by the innumerable mouths of the tiny canals which convey the sweat from the deep-seated sweat-glands to the surface. They can be destroyed, of course, but no different pattern can be put in their place.

Thus, of all the ways of knowing who is who, this is the most certain, as well as much the simplest and cheapest. It is now being more and more used. If a man's thumb-mark is the same as the mark on a piece of paper where a theft was committed, the evidence against him is very strong. A bad man who has become known to the police may change his clothes and the appearance of his face, he may look like a different person, and have not the slightest resemblance to the photograph taken of him, but his thumb-mark will tell him at once. This is now known as the Bertillon System.

How many words there are in the English language

A dozen great scholars might give as many answers to this question. One of them, some years ago, gave the number as only 38,000. But a still greater scholar, Professor Max Müller, who, was perhaps, the greatest authority of his time on words, put the number of words in the English language at 100,000. He compared the growth and development of our language with the putting of grain in a sieve. Most of the chaff has been winnowed off, and with it have gone many good grains. Good old English words, which we now consider only dialect words or "Americanisms," have gone out of the language. If we include all the words which have fixed places in the dialects of the country, and include also many which we know were spoken in earlier times, we shall have to put the total at 300,000 for the English language.

That number is constantly growing. Words have to be invented for new industries, and they become part of the language. When a new dictionary was made, not many years ago, it was found that the new words necessary for use in relation to electricity and electrical appliances numbered over four thousand. A similar increase had taken place with regard to other arts and sciences. Most of them are purely technical words, but, little by little, they become common words as all of us know more about science; and so the language grows.

Have we yet discovered all the world?

No, the Arctic and Antarctic regions still possess secrets which as yet no man has been able to solve. Many brave men in fine ships went into the gloom and silence of the frozen regions in the hope of discovering the Poles; but a great many perished in the attempt. Each expedition brought back a little more knowledge; until finally both Poles were discovered. The North Pole by Peary on April 6, 1909, and the South Pole by Amundsen, on December 14, 1911. There is much land still to be explored in Asia. There are parts in the far North of the American continent of which we know very little. So, also, in the great sandy, stony heart of Australia.

The continent of Africa has been traveled from end to end, and from side to side, but we can fix a point on the east coast of Africa and come out at a point on the west coast, and cover ground which no white man has previously crossed.

The aeroplane in warfare

The aeroplane enables us to take real "bird's-eye" views of scenes on the surface of the earth. At first we might think that a photograph taken from an aeroplane to be a mere curiosity, but to the military expert it suggests possibilities of a startling nature in connection with the art of war. It lays bare the maneuvering of armies and the interior of fortresses; robs the decks of ships of their secrets, and it is even claimed that the movements of submarine boats are almost as patent as though they were moving on the surface of the water. So even as a scouting facility the aeroplane will be of first rate importance in the war of the future. The various governments, including that of the United States, have recognized this use to which the aeroplane may be put. The United States has an aviation school at Annapolis where students are taught the use of the aeroplane in connection with warfare. So far the chief experiments at this school have been in connection with the hydro-aeroplane, which rests on three pontoons, attached centrally and at the wing-tips, thus enabling the machine to rise from the water or settle on it with the facility of a water fowl.

Whether the aeroplane may be utilized as an instrument of destruction is a different question. Experiments have been made in dropping bombs on targets representing war vessels but it is not yet established that they can be dropped with accuracy from a swiftly moving aeroplane so as to be of practical utility. Better results have been obtained from a new machine gun invented by Lieutenant Colonel Lewis of the United States Coast Artillery. This gun weighs only twenty-five pounds and discharges 750 shots a minute and the discharge of the gun is practically without recoil. It would seem that a target on the face of the earth might be hit with considerable accuracy from an aeroplane flying at the rate of 60 miles an hour.

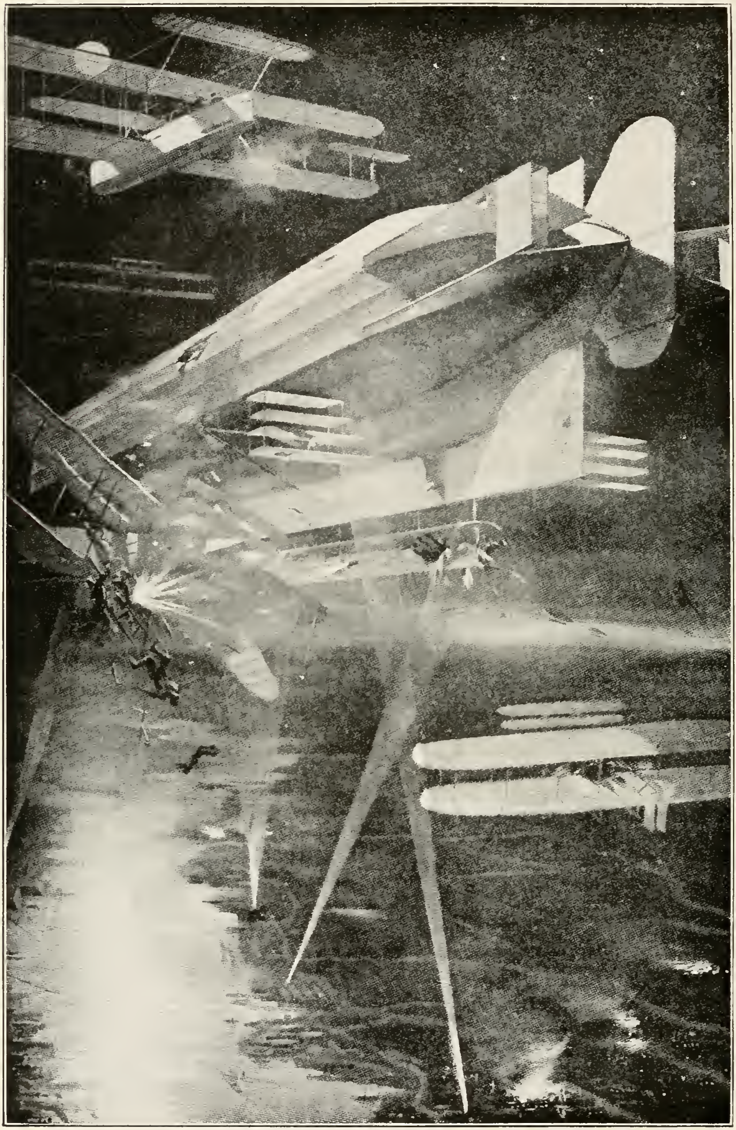
Why the United States is called "Uncle Sam"

This term is used in reference to America exactly in the same way as "John Bull" is applied to England. It arose at the time of the last war between England and America. At Troy, New York, on the Hudson, a commissariat contractor named Elbert Anderson, of New York, had a store yard. A government inspector named Samuel Wilson, who was always called "Uncle Sam," superintended the examination of the provisions, and when they were passed, each cask or package was marked "EA-US," the initials of the contractor and of the United States. The man whose duty it was to mark the casks, who was a facetious fellow, being asked what the letters meant, replied that they stood for Elbert Anderson and Uncle Sam. The joke soon became known, and was heartily entered into by Uncle Sam himself. It soon got into print, and long before the war was over was known throughout the United States. Mr. Wilson, the original "Uncle Sam," died at Troy, in 1854, aged 84 years.

How the American flag originated

The United States Congress passed a resolution on June 14, 1777, declaring "that the flag of the thirteen United States be stripes alternate red and white; that the union be thirteen stars, white in a blue field, representing the new constellation." In 1794, Congress decreed that after May 1, 1795, "the flag of the United States be fifteen stripes, alternate red and white, and that the union be fifteen stars, white in a blue field." This change was made to mark the admission of Ver-

AIRSHIP ATTACKED BY AEROPLANES WHILE BOMBARDING A NAVAL BASE



Stationed in harbors and housed in floating sheds, coast defence aeroplanes must be ready to give battle in their own element to such aerial invaders as may dare to approach their shores.

mont and Kentucky into the Union. The stars and stripes were then equal and a star and stripe were to be added with the admission of each new State. It was realized, however, that the addition of a stripe for each new State would soon render the flag too large, and a resolution was accordingly passed by Congress, April 4, 1818, reducing the number of stripes to thirteen—representing the original Union—and making the stars twenty in number. It was, furthermore, enacted that a new star should be added for each new State admitted into the Union.

The first American flag, known as the "Stars and Stripes," was, according to our best information, made by Mrs. Betsy Ross of Philadelphia, about whom succeeding years have thrown a glamor of patriotic romance.

The official flag of the United States bears forty-eight white stars in a blue field, arranged in six rows of eight stars each. Two stars were added in 1912 by the admission of Arizona and New Mexico to the Union. The garrison flag of the Army is made of bunting, thirty-six feet fly and twenty feet hoist, thirteen stripes, and in the upper quarter, next the staff, is the field or "union" of stars equal to the number of States, on blue field, over one-third length of the flag, extending to the lower edge of the fourth red stripe from the top. The storm flag is twenty feet by ten feet, and the recruiting flag nine feet nine inches by four feet four inches. The "American Jack" is the "union "or blue field of the flag. The Revenue Marine Service flag, authorized by act of Congress, March 2, 1799, was originally prescribed to "consist of sixteen perpendicular stripes, alternate red and white, the union of the ensign bearing the arms of the United States in dark blue on a white field." The sixteen stripes represented the number of States which had been admitted to the Union at that time, and no change has been made since. June 14, the anniversary of the adoption of the flag, is celebrated as Flag Day in a large part of the Union.

WHAT ARE THE THREE FLAGS IN THE UNION JACK?

The Union Jack is made up of three flags—the English flag of St. George, the Scottish flag of St. Andrew, and the Irish flag of St. Patrick. St. George, who lived about 300 years after the birth of Christ, was a heroic soldier who gave up his life rather than deny his faith at the bidding of a Roman emperor. Edward III adopted his name as a war-cry for England, and the red cross of St. George on a white ground became the English flag. St. Andrew was one of the twelve Apostles, and he was crucified on a cross shaped like the letter X. Some relics of the Apostle are supposed to have been carried to Scotland, and the white cross of St. Andrew on a blue ground long ago became the national flag of Scotland. St. Patrick was carried to Ireland as a slave at the beginning of the fifth century. He lived there for thirty years, founding many schools and monasteries, and died there a very old man. Many centuries afterwards, the cross of St. Patrick became the national flag of Ireland.

WHY THE ENGLISHMAN IS CALLED JOHN BULL

Every country has a nickname, and is represented in pictures by an animal. The British lion is the animal which stands for England, and John Bull is its owner and master. The lion is the country; John Bull is the nation. The name of John Bull comes from a work written by John Arbuthnot, a witty doctor and writer, a great friend of Swift and Pope. He was born in

BIRTH OF THE AMERICAN FLAG

This picture shows Betsy Ross and her assistants making the first American flag at her home in Arch Street, Philadelphia. The flag was first hoisted over a military post at Ft. Schuyler, N. Y.

1667, in Scotland, and died in 1735. The sketch that he wrote dealt with the political affairs of Europe at the time, and the countries were made to appear as if they were men and women.

How the American Indian reached America

This is a much discussed question. In a recent paper Prof. Chamberlain coincides with the more common opinion that the American race came from Northeastern Asia across Bering Strait. However, he does not think that the Indian came from an existing people of Northeastern Asia, but thinks that they came from a Mongolian race which migrated at a very remote period; that they changed considerably in their habitat and that after many ages there was a migration in the opposite direction from America to Asia, thus Americanizing a large portion of Eastern Siberia. The red race and the yellow races of Northeastern Asia including the Chinese and the Japanese, would appear to be akin. This view is largely confirmed by a similarity of facial contour, or hair and eyes and of complexion, and by the fact that the two races are very similar in their mental traits.

But there are others who take a different view: Prof. Ameghino of Argentina, and Prof. Sergi, an Italian anthropologist, believe that the Indian is descended from the South American monkey.

Where the alphabet came from

No one really knows all about where the alphabet came from, because it grew very slowly, like children and like every other good thing in the world. But we know quite well that no ingenious man sat down and made the alphabet, and we know quite well, too, that the alphabet began as pictures.

Just as a child reads or takes things in by pictures long before it can read letters, so men used to read and write by pictures; and then these pictures were gradually made simpler and simpler, until at last they could be used in every and any way, as our letters can. We know for certain that the letter O was at first the picture of an eye, and that gradually men made the picture simpler and simpler, until at last they just drew an O. We know for certain also that the letter I was once the picture of a man standing, and many people think that the letter A was once the picture of a house; and very likely a capital A may have been at first the picture of a pyramid.

Ages and ages ago in Egypt men used both kinds of writing. The priests used the oldest kind, which were the pictures. This was called the sacred writing. But the ordinary people used a different and newer kind of writing, in which the pictures were turned into letters. Not very many years ago, men tried in vain to read the old sacred picture writing of the Egyptians, but they could not. Then they found the wonderful Rosetta stone, and this had written upon it the same thing three times—once in the pictures and once in the letters, and also once in other letters, and so men got the key to the picture-writing, and now it can be read easily.

How many words most of us use

We need not tremble at the number of words it is possible to use. Our greatest writers find quite a small number sufficient for their purpose. Shakespeare, with all his varied writings, used only about 15,000 different words. Milton needed only 8000 different words for "Paradise Lost," while the Old Testament contains fewer than 6000 different words. Some people use only about 800 different words, and most of us use no more than one or two thousand.

The beauty of writing and speech

lies not in the number of words used, but in the choice and placing of them. Simple language is the most beautiful. The finest English writing is in the Bible, in "Robinson Crusoe," and in "The Pilgrim's Progress," and in each of these books the language is so simple that a child may understand, while great scholars find equal delight in it.

Why we have names

Well, we have names for the same reason that everything has a name. If we did not have names, we should have to have numbers, like the numbers on motor-cars, which serve just the same purpose. Now, there are names which have meanings, and there are names which have none, and it is always well to know how much and how little a name means. There is something which we call electricity, which means really that it has something to do with amber, for when you rub amber you get electricity, but people sometimes speak as if the name explained electricity, or as if it explained something else to say that it was electricity. That is because they do not know how little the name means. We might just as well call electricity X—which is the name in what is called algebra for an unknown quantity.

One thing you ought to know, however, is the meaning of your own name. If your name is Theodore, for instance, you ought to know that that means the gift of God. Many of our names have meanings, which you can sometimes find in the Bible.

What the cinematograph is

Cinematograph simply means "moving picture." You take a camera, and run through a number of films one after the other, perhaps at the rate of forty or fifty in a second. Perhaps the camera is looking at the sea, or at a game of football. Then, if you take a magic-lantern, and run the film through it at the same rate as you ran it through the camera in the first place, you can throw a moving picture upon a screen. The eye remembers each separate picture after it has gone just long enough to blend it in your brain—where your real eyes are, at the back of your head—with the next picture that comes along; and so you see the waves or the procession as if you were looking at the real thing.

What the cinematograph teaches

We can learn from our senses even when they deceive us. If the eye did not deceive us so as to make us think we see things for a tiny part of a second after they are gone, the cinematograph would merely perplex and tire us, and would not give us the effect of reality at all. Now, too often the cinematograph was used for silly purposes. But some wise people are teaching us by it. For instance, students can learn how a great surgeon performs an operation a thousand miles away by seeing a living picture of him at work. And men have taken living pictures of wild birds flying home to their nests over the water, the parent birds feeding their young ones, the young ones learning to fly, and so on. Other men have taken pictures of terrible things which we ought to know about, so that we can stop them. Yet other men have made living pictures of the blood running through the little tubes in the web of a frog's foot, so that thousands of people at once can see with their own eyes what the circulation of the blood is, and how the little blood cells tumble over each other as they scurry through these tubes, carrying oxygen from the frog's lungs to every part of its body—just as our blood does for us. Before very long the cinematograph will be used all over the world for teaching, as the blackboard is today!

MISCELLANEOUS QUESTION BOX

Why does a ball bounce?

A ball bounces because its elasticity makes it tend always to spring back into shape whenever flattened. When it strikes some hard object the ball is partly flattened by the impact. It resumes its former shape with such speed as to cause a recoil or bounce. The harder the ball strikes the more it is flattened and the more violent the rebound.

Why does wood warp in damp weather?

When wood is alive it instinctively expands in wet weather, to admit the moisture on which it thrives. Wood that has been cut retains that tendency. It absorbs moisture only across the grain. This causes the expansion known as "warping."

Why are shoes hotter when they are dusty?

Dull or dusty shoes absorb the heat. Brightly polished shoes throw off the sun's rays by reflection.

Why is toast more digestible than bread?

The charcoal on the toast's surface helps to absorb the stomach's acid.

Why does wood decay?

The presence of myriads of parasitic microbes causes wood to decay. The soaking of wood in creosote prevents the microbes from carrying on their work of destruction.

Why are there two buttons on the back of an evening coat?

This fashion dates back to the days when every well-dressed man wore a sword. The two buttons on the back of the coat held the sword belt in position.

What is pumice stone?

Pumice stone is volcanic. It is formed deep in the earth and thrown out upon the surface from volcanic craters.

What was the origin of the word "Lullaby?"

Lilith, according to the legend, was Adam's first wife and was a demon. Mothers, soothing their children, would croon the words "Lilith abi" (meaning, "may Lilith keep away from you!") The phrase became corrupted to "Lullaby."

Why does dampness make wood decay?

The oxygen of the water combines with the wood's carbon and forms carbonic acid. The hydrogen of the wood is oxidized and decay sets in

Why does a silver dish tarnish more readily than silver bullion?

An alloy is used to make such vessels harder and more lasting. This alloy oxidizes more quickly than the pure silver.

Why are glue and paste adhesive?

The water used with them evaporates rapidly. They insinuate themselves so closely into the pores of the substance to which they are attached that when the water dries the whole mass becomes solid.

Why does the exploding of a cartridge cause a report?

The sudden release and expansion of imprisoned air causes a partial vacuum. The report is caused by the inrush of fresh air to fill this vacuum.

Why does dry wood burn more easily than green?

The dry wood's pores are filled with air, which helps combustion. The green wood's pores are filled with moisture, which tends to put out the fire.

Why is a crowded hall likely to be struck in a thunder storm?

The vapor and heat rising from so many bodies make the hall a good conductor of lightning.

Why won't a polished tin pan bake bread as readily as an iron one?

The bright metal reflects the heat and will not readily brown the crust on the sides and bottom of the pan. Thus the top of the loaf tends to burn before the sides are brown.

What is the origin of pin money?

Pins were once very expensive. Women bought them as a luxury with their extra money. Hence, money to buy luxuries became known as "pin money."

Does a fan cool the air?

No. It makes the air slightly warmer by imparting to it the heat from the face of the person fanned.

What substances go to make up common glass?

White sand silicate, soda ash, lime hydrate, a little antimony, arsenic.

How did the phrase "a feather in his cap" originate?

In Hungary an ancient custom forbade any man to wear a feather in his cap until he had slain at least one Turk. Hence the presence of such a feather was a sign of prowess.

What is the effect of electricity upon water?

The water is reduced to its elements—two parts of hydrogen to one of oxygen.

Why is oak wood stronger than pine?

Because the molecules of the oak have a greater power of attraction for each other and so would take a greater force to separate them.

How long must a pendulum be to vibrate sixty times a minute?

The length of the pendulum that vibrates just sixty times a minute is 39.1 inches in New York; this varies at different points on the earth's surface.

How is stoneware glazed?

By throwing common salt into the furnace. This is volatilized by the vapor of water, which is always present, and the silica of clay of which the air is composed. This fuses over the surface of the ware and gives a thin but excellent glaze.

What becomes of the abundance of carbonic acid gas from the cities?

Some of it is absorbed by vegetables, the rest is blown away by the wind and diffused through the whole volume of the air.

Why does saleratus make cake light, particularly if mixed with sour milk?

The acid of the milk disengages the carbonic acid contained in the saleratus.

Why does mortar become hard after a few days?

The lime reimbibes from the air the carbonic acid which has been expelled by fire, and the loose powder again becomes as hard as the original limestone.

Why does an extinguisher put a candle out?

The air in an extinguisher is soon exhausted of its oxygen by the flame, and when there is no oxygen the flame goes out.

What are meant by latitude and longitude?

Latitude is the distance north and south of the equator. Longitude is the distance east or west of the line of Greenwich near London.

What is the weight of a cubic foot of gold?

About 1200 pounds.

How long ago was shorthand used?

Shorthand probably originated in Greece or in the Orient. It is known to have been in common use in Rome as early as 63 B. C. and was employed by Tiro, Cicero's secretary, to report his master's speeches in the Roman senate.

Why are the edges of gold and silver coins "milled?"

Silver and gold coins used to be "pared," or scraped at the edges by unscrupulous people, who collected and sold the fragments of precious metal thus obtained. To prevent this the edges were "milled." Copper and nickel are not of sufficient value to make "paring" worth while, So copper and nickel coins are not milled.

Why is ice slippery?

Ice is slippery because the molecules of water are held together so smoothly and evenly that no resistance or friction is offered.

What were the seven wonders of the world?

The pyramids of Egypt, the hanging gardens of Babylon, the temple of Diana at Ephesus, the statue of Olympian Jupiter at Athens, the Mausoleum, the Colossus of Rhodes, the Pharos (lighthouse) at Alexandria.

Why are three gilt balls used for pawnbrokers' signs?

The Medici family of Florence were money lenders. Their coat of arms bore three gilt balls.

What is the derivation of the word "spinster?"

In olden days a woman did not marry until she had spun a full set of household linen. Thus, till they were married, they were known as spinners or spinsters.

Where did the United States get the decimal system of coinage?

Gouverneur Morris in 1782 reported to congress a decimal system of currency, using as a basis the 1140th part of a Spanish dollar, which, he calculated, was a common divisor of the various currencies. With this fractional sum as a unit he laid out a monetary system. Jefferson in 1784 improved on this by suggesting four standard coins—$10, $1, 1 dime and 1 cent.

When and from what country was the wearing of orange blossoms by brides introduced into Europe?

From Syria, at the time of the Crusades.

How did the custom of throwing shoes after a departing bride originate?

The dropping of a shoe on a piece of property was once a symbol of new ownership. By throwing shoes after a bride her parents signified that they gave up all claim to her.

What is the origin of the word "hurrah?"

It comes from the Slavonic phrase "hu-ray," meaning "To Paradise!" This was a battle cry among the Slavs.

Why are members of tropical races dark-eyed?

The dark color defends the eyes from the intense heat of the sun, which would otherwise scorch them.

Why does paint keep iron from rusting?

Paint prevents the moist air from coming in contact with the iron.

Why is it hard to write with ink on greasy paper?

Grease will not readily mix with water or ink and prevents the ink from being properly absorbed by the paper.

What is the origin of the ring in the marriage ceremony?

Its use began in Egypt, and then, as now, signified a transfer of property—"With all my worldly goods I thee endow."

What good effect has rain falling on dead leaves?

It hastens the decay of the leaves, thus helping to fertilize the earth.

How is the red fire in fireworks produced?

By nitrate of strontian, which burns with a red flame.

What are the uses of cast iron and steel?

Cast iron, being brittle, is used chiefly for stoves, furnaces, etc. Steel's superior hardness and flexibility renders it useful for making springs, tools, etc.

Why does mother-of-pearl show so many colors?

It consists of many transparent layers overlapping one another and thus forming grooves that run in all directions. The grooves act as prisms, in which various colors are seen.

Why are dreams usually illogical and absurd?

The cerebrum (the reasoning part of the brain) is at rest during sleep.

What is German silver?

It is an alloy of copper, zinc and nickel.

What are three forms of iron?

Wrought iron, cast iron and steel.

What are the most important uses for common salt?

As a part of the diet and for freezing mixtures and for purposes of manufacture.

What are the different kinds of coal?

Anthracite (hard) and bituminous (soft). Forms of coal in transition state are lignite and peat.

How are mirrors made?

They are of plate glass, backed by an alloy of thirty parts mercury and seventy parts tin.

What is plaster of paris?

Gypsum is heated and afterward powdered. This produces plaster of paris.

Why is rain water better than any other for plants?

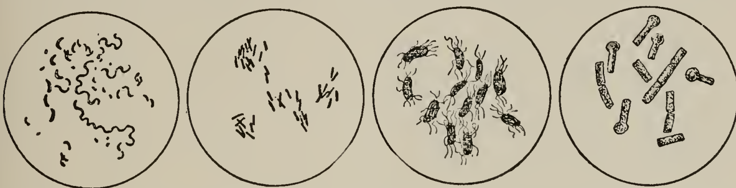
It contains carbonic acid and ammonia, which serve as fertilizers.

What is shale?

Shale is a form of slate that splits easily into thin, brittle layers.

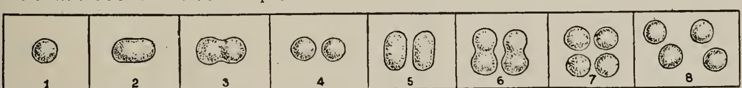
THE INVISIBLE ARMIES THAT MASTER THE EARTH

These pictures show us what is going on in our bodies almost every moment we live. Our bodies are inhabited by millions of living creatures, always fighting to make us ill or keep us well. In the first circle we see the little white things, called phagocytes, that live in our blood and keep it pure; in the second we see them devouring microbes which do us harm. The third circle shows the growth of a microbe. The small rings are the seeds, which grow together like a little stick and split up. The long, thin things that are growing out of them are the things they move with, what we should call legs and arms. The last picture shows what a colony of microbes looks like, and we see separate microbes going out to form other colonies.



This is a row of our microbe enemies, shown 1,000 times bigger than they really are. The first are the microbes that cause cholera, the second cause consumption, the third cause typhoid fever, and the last cause lockjaw. These powerful creatures are so small that 140,000 could be placed side by side on a line as long as a pin.

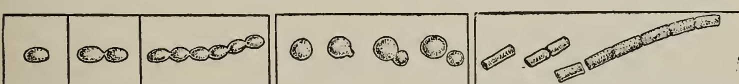
This is a row of our microbe friends, shown 1,000 times bigger than they really are. The small microbes at the top in the first circle make milk sour; those below help to make butter and cream. In the second circle are the microbes found in yeast, which make alcohol; in the third is the microbe that makes vinegar; and in the last circle is a microbe that helps to make cheese. We could not live without such microbes as these.



1	2	3	4	5	6	7	8
A microbe beginning	About five minutes later	After 15 minutes	It grows into two	Both begin to develop	Both form "waists"	The two become four	At the end of an hour

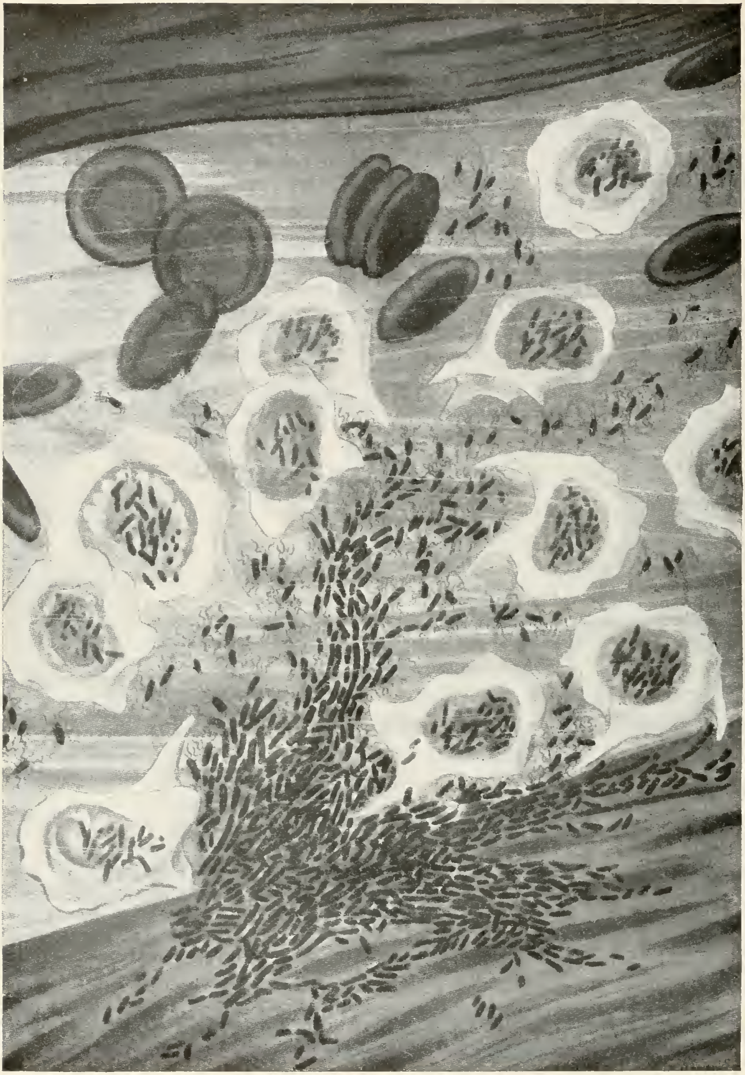
Microbes cannot be seen without a magnifying glass, but we can watch them working with a microscope.

THE WONDERFUL WAY IN WHICH MICROBES ARE BORN WHILE WE LOOK AT THEM



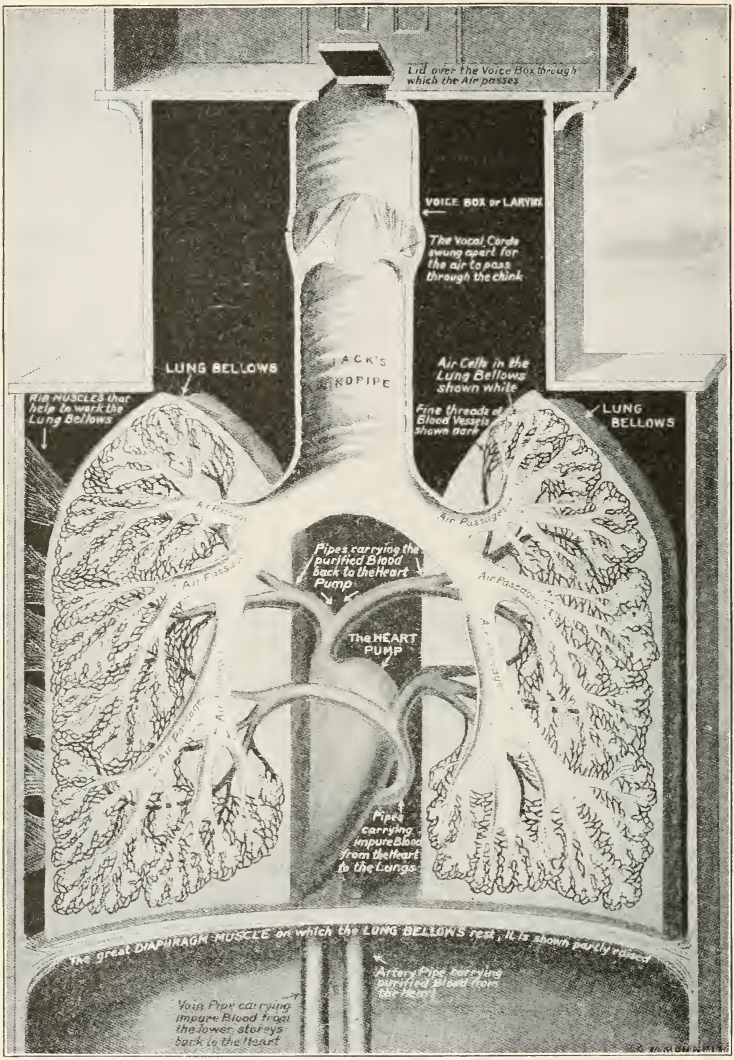
These pictures show the way microbes grow. Some form a "waist" and add other microbes to themselves like a string of beads. Others form buds, which break off and become separate microbes. Others join together in long rods and break off afterwards. And so these little creatures grow, more quickly than any man can count. In 24 hours, if they all lived, the children of one microbe would form a line reaching from end to end of England, and if the microbes were as big as shown here this line would be long enough to go 20 times round the earth.

THE ENEMIES THAT STEAL HEALTH



This shows what happens in a drop of blood when we are ill. The little black "burglars," invisible to the eye, are phoid fever parasites, and the white cells of the blood are attacking them. If the white cells win the battle, we recover they lose, we die. We see this under the microscope.

Book of Our Own Life



In this picture we see how the human house is ventilated. The air goes down the voice-box and windpipe and into the lungs, or bellows, which are very much like sponges, with thousands of tiny hollow spaces lined with living cells. These cells lie between the air and the blood in the hollow spaces, and they purify the blood by taking the oxygen from the pure air and sending it into the blood, and by driving the carbonic acid gas and water from the blood into the air, to be breathed out again. The impure blood is always being pumped through the lungs to be purified in this way. In the picture the blood-vessels of the lungs are shown dark, and the air-passages light.

THE BODY A HUMAN HOUSE

THIS human house of ours is the home of the soul. It is the wonderful and mysterious home which God provides for each of us and of which we should learn to take the best of care.

Just as with houses built of timbers or of stone, so this house of ours is made up of many rooms. Each room renders its special service and demands of us in turn, a special care. When we are hungry, the stomach room, or Great Furnace of our house is in need of wholesome food. This food after undergoing a wonderful change is absorbed by the blood, and then through a net-work of arteries and veins is carried to the skin, the nerves, the muscles, and the bones, and thus nourishes and builds up our body.

Need of fresh air in the house

But food alone cannot make this house of ours a healthy place in which to live. The lungs, the Ventilators of the house, must be filled and refilled many times each minute with pure, fresh air. The air breathed deep into the tiny cells of our lungs, meets and purifies the impure blood which has been sent there by the heart, the Great Pump of our house. This Great Pump of our house is kept busy every minute of our lives: First, it must gather the poisoned and waste-laden blood from every part of the body and send it to the lungs; then with tremendous force the pure blood is pumped through the arteries and the veins on its long journey to every part of our body. Sometimes, Enemies, or invisible living things called Microbes, creep into our house and try to steal away our health, but wholesome food, fresh air and an abundance of sunshine and exercise will drive these Enemies away.

The busy sentinels in the first story

The top story of our house is supplied with busy sentinels, the eyes, the ears and the nose, which are always on guard to protect our house against its Enemies. For example, if we breath through the nose, the air is tested and filtered of impure particles; what we carry to our mouths is closely examined and tested by our tongue before it is admitted to the stomach; and the knowledge thus gained from touching and tasting and smelling helps train the outer sentries, the ears and the eyes to be on guard, and to warn of approaching danger.

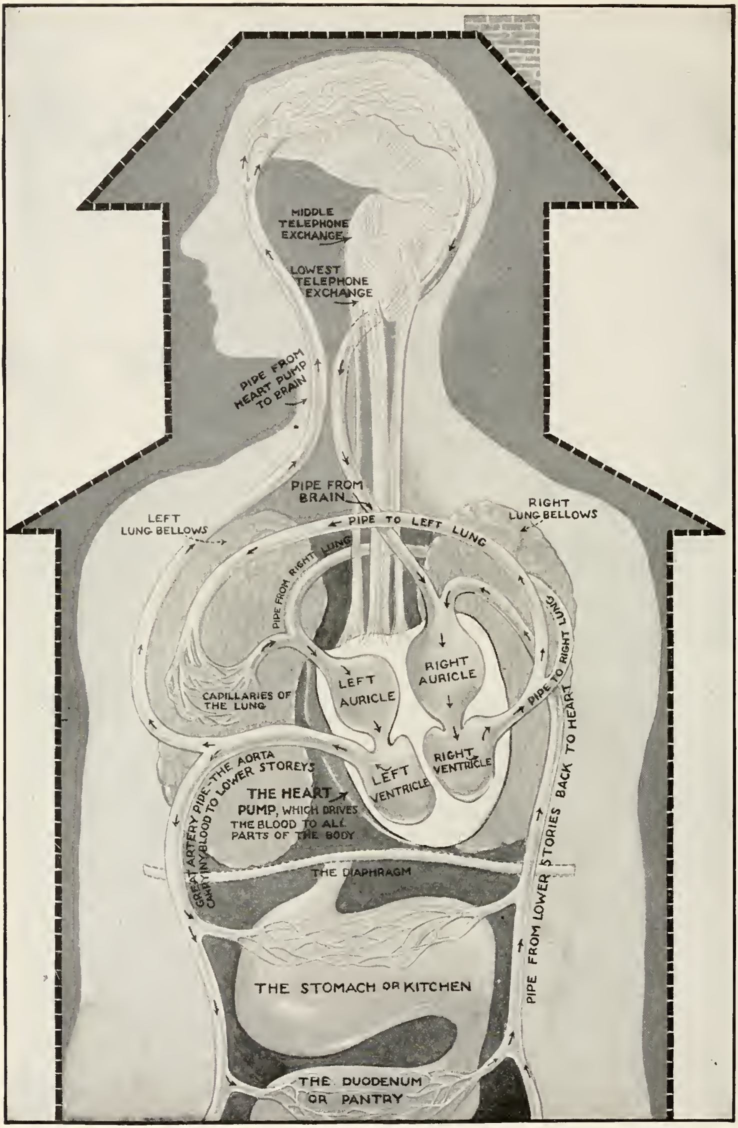
Our telephone exchange, the master of our house

We may correctly call the Brain our Telephone Exchange. It is connected with every room and every part of our body by a network of nerve fibers —Telephone Wires. These nerve fibers are usually gathered into insulated cables called nerve trunks, and over these nerve trunks travel the lightning messages to and from the brain, the master of our house. In this same manner the sound vibration travels over the Telephone wires that extend everywhere throughout a city and unite at the central exchange.

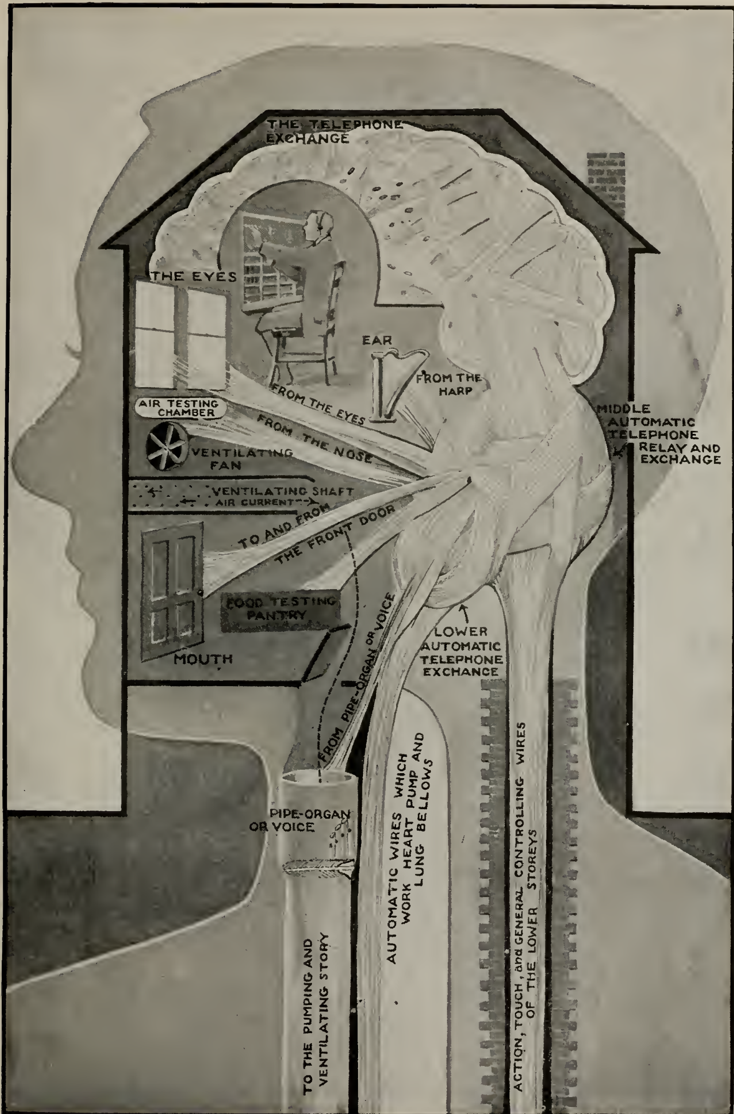
A wonderful story most wonderfully told

How important it is to know how to keep in perfect order the many rooms of this marvelously constructed house of ours; what guests to invite there and against whom every door should be closed. All success and happiness of life, even the house itself, may be wrecked by a single act of ignorance or neglect. The Book of Our Own Life tells the story of the things we should know about ourselves—how we should live in the house not built with hands.

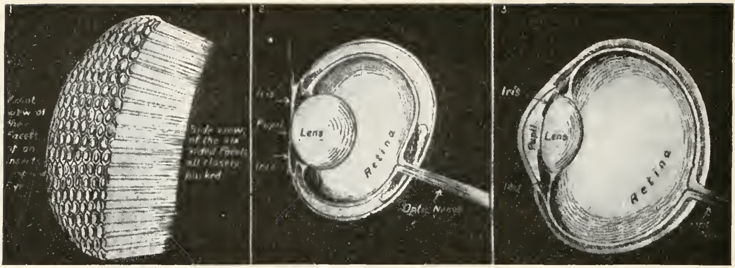
BLOOD CIRCULATION IN THE HUMAN HOUSE



This picture shows the wonderful pump, called the heart, in the middle of the human house, and we can see here also how the ovens and corridors are linked up with the top story. The heart pumps blood through the body, and if we start at the right ventricle, and follow the arrows, we can trace the course of a drop of blood through the body back to the heart.



The study at the top of the wonderful house which builds itself, and from this room run the telephones and telegraphs by which we control all our affairs.



The first picture shows the eye of a fly, the second that of a fish, and the third that of a man, and we can see, by comparing these, how much nearer the fish's eye is to a man's than is that of an insect.

STORY OF THE EYE

THE sense which we are now going to study is vision, or seeing, and the organ of this great sense, as everyone knows, is the eye. In many ways, this is the most wonderful and important of the senses. It is so for the purposes of practical living. It is more necessary to see than to hear, or taste, or smell. A blind man is at a greater disadvantage than a deaf man. The progress and ascent of living creatures on the earth have very largely depended upon vision, and we have already learned that the vision part of the brain is largest in the highest forms of life. It is much larger in ourselves than in any other creature.

Vision is also of the highest importance for our ideas of the world in which we live, just as it is for our practical doings in that world. If we could not see we should know very much less of our own earth, and we should know the sun only by the radiant heat that it sends us; and all the other heavenly bodies would be unknown to us—from our own little moon to the millions of stars. It is upon our eyes, then, that our knowledge of the great world beyond our own earth depends, and on this claim alone our eyes are entitled to special respect. Unlike any of our other senses, they put us directly in touch with the infinite and the sublime.

One of the greatest men who ever lived, said that there were two things which filled him with awe—the feeling of duty inside the minds of men and the starry heavens above us. Let us begin, then, by studying how, in the course of long ages, living creatures have been able to develop the eyes by which the starry heavens are seen.

This question of the history of the eye is deeply interesting. A short time ago we should have begun at once with the history of the eye in the animal world. It would not have occurred to anyone that there was anything to say about eyes or seeing in the world of plants, but it has just been discovered that seeing, of a kind, at any rate, is not confined to the animal world. There are older eyes than any backboned animal, at any rate, can boast of, and we find them among plants. If we are really to understand our own eyes, therefore, we must begin at the beginning, with something much older and simpler than our eyes or any part of us.

The eyes of plants are very simple. The business of a green plant, and especially of the leaf of such a plant, is to receive and use the light that falls upon it. It is therefore in the leaves of plants that we find their eyes. Simple experiments—which have now been made many times over, with many kinds of plants—show, to begin with, that somehow or other the leaf gets to know about the light.

For instance, if the direction of the light is altered, in a very short time the leaf turns itself, so as to get the light fair and square upon its surface; and some leaves will do this as often as the direction of the light is changed. We may, perhaps, get rather wrong ideas if we say that the leaf sees the light, yet that must be what happens; only it is a very simple kind of seeing.

The Little Eyes by which a Leaf can See

After it had been completely proved that somehow or other the leaves can see, the next thing, of course, was to find whether the leaf saw as a whole, or whether it had any special places where it saw—places which must be called eyes of a kind. When the surfaces of leaves were carefully examined, it was often found that there were places where there was developed a kind of simple eye. That is to say, certain of the cells forming the surface of the leaf were made of a special shape; it was found that the outside of these cells is curved, just as the front of our eyes is curved.

The consequence is that light falling upon these cells is focused, as we say, and thrown upon the floor of the cell, just as a curved piece of glass will focus the sun's rays and throw a bright spot on a piece of paper. If the leaf is at right angles to the light, then the bright spot made in this way will fall right on the middle of the floor of the cell.

What Happens When A Leaf Does Not Look Straight At The Light

This corresponds to what happens in our eyes when we are looking straight at a thing, and the picture of that thing falls, as we shall soon learn, upon exactly the right place at the back of our eyes—the place where we see best. But—when the leaf is not facing the light—not looking straight at it, as we might say—the little bright circle that should fall upon the middle of the floor of the cells is thrown somewhere to one side of the floor, or may even be thrown not upon the floor of the cell at all, but upon one of its walls; and the life of the cell knows the difference.

Of course, these discoveries have excited the greatest interest, and at first many doubts were expressed, but these have all been cleared away. In the first place, it was necessary to prove that the curving of the surface of the cells really made them act like little lenses.

In two ways this can be proved; either the surface of the leaf can be shaved down, so that it becomes flat, or else a little water can be laid on the leaf and then covered with a thin sheet of glass, in such a way that the water fills up the hollows between the cells, and so makes the leaf flat, whereas before it was covered with hundreds of little bulging eyes.

When these experiments were made, it was found that the plant no longer responded to the light; the leaf no longer turned so as to face the light directly—in a word, it no longer knew where the light came from. Its sight had been spoiled just as our sight would be spoiled if something of the kind were done to our eyes.

Photographs That Can Be Taken With The Eyes Of A Leaf

And then, still more lately, the power of these little eyes was proved in another way. If these cells with their curved fronts really act as lenses, then, with care and skill, it ought to be possible to make them take photographs—that is to say, it ought to be possible to use these little cells as the lenses of a hundred tiny little cameras. This has been done, and the most excellent photographs have been taken —photographs so good that the person photographed can quite easily be recognized when the photograph is magnified and thrown on a screen.

This subject is quite new, and we are only at the beginning of our knowledge of it. A beginning has been made, however, with a new chapter in our knowledge of plants and their wonderful lives. Here, it is sufficient just for us to know that plants, which live by the light of the sun, and upon whose life our own lives depend, have little eyes of their own, which they use for their lives, and therefore, in the long run, for ours. It is because all animal life depends upon plants that we should know these things. And now we can go on and study the history of the eye in the animal world.

In the very lowest forms of animal life we find that there is response to light, for we find that some of the simplest kinds of animals will always travel from shadow into the light, and others will always travel from light into shadow. These are creatures whose bodies are so simple that we should not look for any special organ of vision.

HOW THE FIRST TRACE OF AN EYE IS FOUND IN THE SKIN

Probably the first trace we have of such an organ—that is to say, the first trace of an eye—is where we find that, in certain lowly animals, parts of the skin are very sensitive to light. We find in such cases that the color of the animal changes according to whether it is in light or in darkness or in shadow, and when its skin is examined under the microscope, we find that it contains a large number of cells packed with colored material.

This is usually called pigment, which is simply the Latin for paint—in fact, another form of the word paint. These pigment - cells are sensitive to light. When light shines on them, all the pigment is gathered tightly up into the body of the cell; but when the light is taken away, and they are in shadow, the pigment strays out in all directions from the center of the cell, and so is scattered.

This explains why the color of the animal changes, and it also tells us why and how the animal is able to know what the state of the light is, and to act as it pleases accordingly. In the study of the history of the eye, great stress has always been laid upon these pigment-cells; but now that we have discovered such wonderful eyes in leaves, fitted with lenses so perfect that they will take photographs, the pigment-cell, which we look upon as the beginning of the animal eye, seems to be a very poor affair compared with a plant eye.

THE LITTLE CELLS IN THE SKIN UPON WHICH LIGHT ACTS

We do not know exactly how it is that light affects the pigment-cells, but we may be sure that the action is really a chemical one. Everyone who is interested at all in photography knows that light has a chemical action —as, for instance, on the salts spread on a photographic plate. Every housewife whose curtains fade, or who puts clothes out to be bleached, knows also that light has a chemical action. Its action on the pigment-cells is chemical also; and when we come to study what happens in our own eyes when the light strikes the curtain at the back of them, we shall find that what happens there is very like the action of light when it takes the color out of a curtain or a gown.

What happens next in the history of the eye is that the pigment-cells, which were at first scattered about the surface of the body, get to be specially collected in certain places. These cells are not quite on the surface of the skin, but are underneath the outer skin, and the next stage is that, at the place where the pigment-cells are gathered together, the outer skin, or epidermis, becomes thickened, and bulges a little. Now, this is very important, because if we have a bulging or a curved surface, through which the light must pass on its way to the pigment-cells, we have indeed a lens of the shape called *convex*, and, as we know in the case of the burning-glass or the lenses of leaves, the result is that the light is focused.

The simplest kind of eye, and the wonderful eye of a fly

Now, we have already learned enough to be sure that these pigment-cells, like every other part of the body, are connected by nerves with the brain. So now we have reached the stage where there is a lens to focus the light, sensitive cells to be chemically affected when the light falls upon them, and nerves that somehow convey a record of these changes to the brain, which therefore sees. Here, then, is a simple kind of eye, complete from the surface to the center.

All the eyes of animals that have no backbone are to be looked upon as simply improved patterns of this kind. The eye in such creatures is always developed from the skin in the case of each individual, just as we have learned that, in the history of these animal forms, the eye has gradually become developed from the skin. We shall soon see that the eyes of backboned animals are of a much higher type; but we must not underrate all the eyes below backboned animals, because it is very certain that the eyes of some insects are exceedingly keen. It is generally agreed that the dragon-fly is the most wonderful insect of all in this respect. Its eyes are extremely large and powerful.

As in many other cases, the lens of the eye, instead of being just curved in one single simple bulge, is like a large diamond that has had its face cut into a number of little flat surfaces. These little faces of the lens are usually called facets. The number of facets upon the lens of the eye of the dragon-fly is very large.

How the dragon-fly amuses itself by amusing men

Few things are more wonderful than the certainty and skill with which the dragon-fly will recognize, follow, and catch the smallest insect on the wing. One of the greatest living students of this subject, Professor Forel, one of the many wise men who have made Switzerland famous, writes as follows: "By trying to catch them at the edge of a large pond, one can easily convince oneself that dragon-flies amuse themselves by making sport of the hunter; they will always allow one to approach just near enough to miss catching them.

"It can be seen to what degree they are able to measure the distance and reach of their enemy. It is an absolute fact that dragon-flies—unless it is cold or in the evening—always manage to fly at just that distance at which the student cannot touch them; and they see perfectly well whether one is armed with a net or has nothing but his hands. One might even say that they measure the length of the handle of the net, for the possession of a long handle is no advantage. They fly just out of reach of one's instrument, whatever trouble one may give oneself by hiding it from them and suddenly lunging as they fly off."

We must not suppose that all insects have good eyes; there are all stages between the dragon-fly, at one extreme, and insects which are completely blind, as, for instance, the cave-dwelling insects and certain kinds of worker-ants which live entirely underground.

The house-fly that has learned to keep away from the gas-flame

The rule for most insects is that they fly towards the light. Artificial lights, such as we use, do not occur in Nature, and an insect flying towards a lamp really supposes that it is flying towards the light of day. It is most unfortunate, from our point of view, that a good many domestic insects have learned in the course of many years to know what artificial light is. We cannot now enter into the very difficult question how it is that this change has been brought about in their natural habits; but, at any rate, it is the case that such an insect as the ordinary fly does not destroy itself by flying against a flame.

The habits of flies are extremely dirty; their feet are always laden with filth. They are thus great carriers of disease, and destroy many babies every year by poisoning their food. That is why it is very unfortunate that flies have learned how to behave to artificial light in what, for their ancestors, would have been an unnatural way.

Many years ago Lord Avebury showed that bees and wasps were able to distinguish colors; but wasps are very inferior to bees in this respect. Bees distinguish all colors, and very rarely make any mistake except between blue and green. The importance of this is very great, because it largely helps to explain how it is that bees are able to distinguish one flower from another.

Insects that can see what our eyes cannot see

As a rule, the color of a flower is a kind of flag held out to say to a bee or other insect: "Come here; I have something that you will like." So the bee gets its honey and the flower gets fertilized. Thus we owe the pleasure our eyes get from most of the beautiful flowers we know to the fact that the eyes of bees and other insects are able to see them and to distinguish them. If there were no insects there would be no beautiful flowers; there would be nothing for the plant to hang out its flag for.

It was also proved by Lord Avebury, that ants, for instance, can see kinds of light to which our eyes are blind—that is to say, the light which lies beyond the violet, and which is known as *ultra-violet* light.

Here we may notice, what has recently been shown, that people's eyes vary in this respect. Just as old people do not hear high-pitched sounds, which younger people can hear, so we find that there are a good many young people who, somewhat like ants, can see a little way, so to speak, into the ultra-violet, where, to the rest of us, it is quite dark. Finally, Lord Avebury has shown that ants are able to recognize each other after more than a year of separation. Let us beware of judging the value and power of things by their size, and let us learn from this brief account of one of the senses of insects that we still have reason to go to the ant to "consider her ways and be wise."

Now we must pass to the eyes of backboned animals. The lowest kinds of backboned animals are the fishes, and we have all seen the eyes of fishes. Wonderful and skilful as the eyes of insects may be, the eyes of backboned animals are of a vastly finer and more wonderful type. In the first place, this seems to depend upon a change in the making of the eye. We have seen that the eyes of all the animals that have not backbones are entirely formed from the skin; but the higher type of eye found in backboned animals has its most important parts developed from the brain, and not from the skin at all.

True, the front part of such eyes as our own is formed from the skin, but that is only true of the parts through which the light travels on its way to the all-important curtain which makes the back of the eye. That curtain is really a part of the brain which has been pushed out, as it were, from the brain upon a kind of stalk or stem.

The real reason why the curtain, or retina, of the eye of backboned animals has its great powers—vastly superior to those of any lower type of eye—is that this retina is, indeed, a part of the brain itself. Vision is so important that the business of receiving light-rays could not be left to anything developed from the skin; so a portion of the brain itself extends forward to form a portion of the eye and especially the retina.

In main principles, the eye of backboned animals is much the same, no matter which particular animal we take. The eye of the fish is certainly very much inferior to that of a bird or a mammal, as we should expect, if we consider that the fish has to see only in water, where it would be impossible for any kind of eye to see more than very short distances; but even the eye of the fish is, in all the main points, the same as our own, though much simpler.

We need not discuss specially the eyes of birds, though everyone knows that they have some powers superior to those of the eyes of any other creature. These powers are in the direction of keenness, so that we say of anyone who is very sharp to see things that he has the eyes of a hawk. This keenness is at its best in the case of the hawk and other birds of prey, but other birds also have very keen eyes. They could not catch flying insects if they had not. In praising the eye and the keenness of vision in birds, and in studying their eyes, we must not make the mistake, which is commonly made by almost everyone who has studied this subject and written upon it, of supposing that mere keenness of vision is everything.

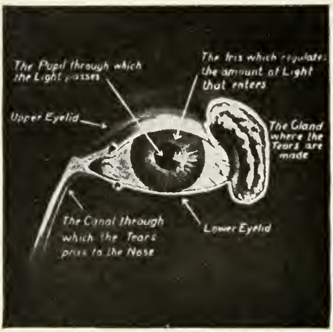
It is easy to see what a mistake that is, if we consider the case of a sailor, for instance, who has very keen eyes indeed, and can see far into a fog, but who would perhaps never cast a second glance upon the most noble picture that was ever painted, or upon the most lovely landscape. On the other hand, a great artist may be old and very nearly blind, and though his vision is very dim, yet he can see in a sunset or in a picture things which mere keenness of vision, whether in a man or a hawk, could never see at all. This is worth remembering, for it is just as true of all the other senses as it is of vision.

Keenness is not the highest quality of a sense, and the best proof of the rightness of our view is to be found in the fact that, when we test the matter by the brain, we find that the vision area is largest and most highly developed, not in the insect or the bird, or in the men with the keenest eyes, but in the brains of the highest type of men, who have learned to see and love what is beautiful and poetic.

THE EYELID THAT WASHES THE EYEBALL AND KEEPS IT MOIST

And now we are prepared to look at our own eyes and see how they are made. It is proper to mention the eyelids, because they exist for the sake of the eyes, and the eye cannot get on without them. We are very wrong if we suppose that the eyelids merely exist in order to cut off the light when we do not wish to see. They have that purpose, but if we had to do without them, and replace them by an artificial shade, we should soon find that that is not the whole of their use, but that they have another use that is of the greatest service to the eyes.

Every time that we wink—which we do every few seconds without thinking about it—the upper eyelid washes the front of the eyeball by means of a tear which has come from the tear-gland, and has been spread over the inside of the upper eyelid.



The left eye, showing the glands where the tears are made and the ducts through which they are carried to the nose after washing the eyeball. In weeping, the tears cannot all pass through the ducts, and so they overflow.

The tear-gland lies above the eyeball, a little to its outer side. The tear, after washing and moistening the front of the eyeball, passes through a tiny hole at the inner end of the lower eyelid into the nose.

Why we cry when we are in sorrow or distress

The reason why we cry when we are distressed seems at first to be that the part of the brain connected with the tear-glands lies very close to the part of the brain which is disturbed when we are made unhappy.

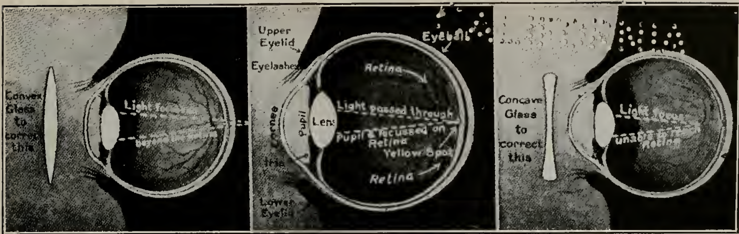
The real reason, we may believe, why we show signs of distress in our eyes rather than anywhere else is that we human beings live by one another's help and sympathy and love. We are meant to see when others are unhappy, so that we may know, beyond any doubt, when they are needing our sympathy and help.

If a child's mouth merely watered when it was unhappy, we should not know, and therefore would not help it; but when we see its eyes water our sympathy is aroused, and we help it. We cry, not because the brain happens to be so made, but the brain has been so made because crying is the most useful and convenient way in which our distress can be shown to others.

How the face and the eye express our feelings

As the higher parts of the brain develop we learn self-control, and cry very much less readily than when we are quite young; but it is still true that our feelings find expression that can be seen by other people, for the face shows our feelings, and when we make a general study of the way in which our feelings are expressed by the various parts of the face, we shall see that crying fits in with these other ways of expression as the watering of the mouth would not, so that it is more than a mere chance that sorrow and sadness find expression in the shedding of tears rather than in the production of saliva or in some other way.

The eyelids are provided with hairs which help to protect the eyes from dust. Besides the protection afforded by the eyelashes, the eyebrows are to be reckoned with, as they prevent the sweat of the forehead from running into the eye. Lastly, we have to notice the well-contrived bony structure of the skull around the eye, which furnishes a very wonderful protection.



In the middle picture we see a section of a perfect eye, with the light focused correctly on the retina. The left-hand picture shows an eye in which the cornea is too flat, and the light being focused beyond the retina causes indistinct vision. The eye on the right hand has the cornea too convex.

PARTS OF THE EYE

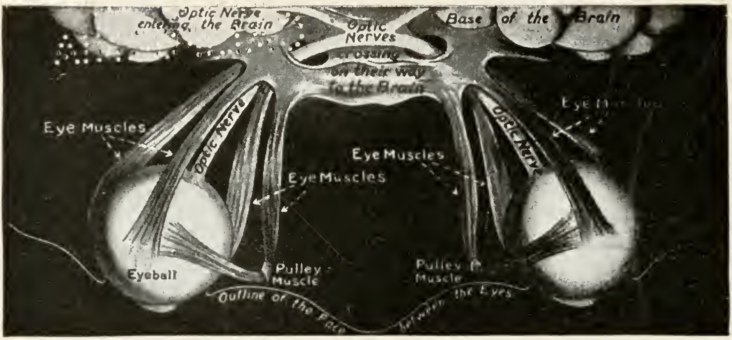
WHEN we examine the eye, the first thing we notice is that the front of it is transparent. This round, transparent part in front is called the cornea, which really means the horny thing. If we look very carefully at it, we shall see that it bulges forward somewhat. The curve of it is not quite the same as the general curve of the eyeball. This shape of the cornea is very important because of its effect on the rays of light that enter it. It acts just like the curved surface of the eye-cell of a leaf.

The first and greatest business of the cornea is to be perfectly transparent. It contains, therefore, no blood-vessels, small or great; it would not do to have red or white blood-cells in the cornea interfering with the passage of light. But the cornea is alive and must be fed, and it is supplied by materials that pass to it through the walls of the tiny blood-vessels that we find all around its edge. The cornea is well supplied with nerves, nearly all of which run to its front surface, in order that it shall be very sensitive.

This is necessary so that the least speck of dust or anything else that would injure it, shall be felt and wiped away by the eyelids and the tears. Only too often, however, a workman gets what he calls a "fire" in his eye, and then there is a great risk that, when the cornea recovers from the injury, the injured place will be opaque for the rest of his days. Also, when anything of this kind happens to the cornea, blood-vessels grow into it from the side. They must do so, for they must supply food and other materials to the injured part, if it is to recover; but these blood-vessels mean that the passage of light is interfered with.

Recently the first attempt that has ever succeeded was made to remove a piece of cornea that had become opaque, and to graft there a piece of healthy transparent cornea. It is well for us to understand how important and wonderful this part of the eye is. All the light we see by must pass through it; yet it is a living thing, with all the needs and delicacy of a living thing—very different from a curved piece of glass. Lastly, it is very much exposed, though, as we know, the eyelid, eyelashes, eyebrow, and the bony wall around the eye do their best to protect it.

All round its edge the cornea passes into the white, thick, strong coat of



This picture helps us to understand how the eyes grow out of the brain, the optic nerve projecting till it expands into the hollow cup of the eyeball. The muscles that move the eyes are also shown.

the eyeball; indeed, the cornea is really a special part of this strong outer coat of the eyeball that has been made transparent, and has been made to bulge forward a little in order to help in focusing the light. The white outer coat of the eyeball is very strong, and will stand a good deal of pressure. If we feel one of our own eyes with the finger, we shall find that it is quite tight; and the existence of this pressure in the eyeball, which is supported by the outer coat, is of great importance for good seeing.

Now, when we look at anyone's eye, we see something through the transparent cornea. We see a round, colored ring with a black hole, small or large, in the middle of it. The colored part is called the iris, and it is a ring of muscle with a hole in the middle of it, which is the pupil. This looks black because it is really the hole leading into the dark chamber, or inside of the eye, which is like the inside of a camera. Now, if we could be shown an eye cut through sideways, we should see that there is quite a large space between the cornea and the front of the iris. This space is filled with a watery fluid, and the light has to pass through this fluid before it is able to reach the pupil.

THE PUPIL OF THE EYE THAT GETS BRIGHT IN A DIM LIGHT

The business of the iris is to regulate the size of the pupil. The less the amount of light, the larger must the pupil be; and the more the light, the smaller the pupil. So when a person goes from darkness into light, or when the eyes are opened in a bright light, anyone may see that the pupil gets smaller. We can also notice that the pupil gets smaller if a person who has been looking at something far away suddenly looks at something close to his eye. There is a special reason, rather difficult to explain, why it improves the clearness of vision to reduce the size of the pupil when looking at something near. The cause is to be found in the shape of what lies behind the pupil, as we shall soon see.

All the color of the eye is due to the iris. The color is not to be found at all in the muscle fibers that make the iris; they are just like other muscle fibers, and are the same in everybody. But both on the back and front of the iris there is a layer of cells, which may or may not contain a certain amount of pigment, or paint. It is this that varies in different people. It is interesting from the point of view of beauty, because its variations in different people provide many different types of beautiful eyes. But the color of the iris has quite lately become most interesting, because we are just beginning to learn what are the rules as to the way in which eye-color descends from parent to child. This is one of the subjects which is being closely studied by scientific men all over the world, and we are no doubt going to learn a great deal from it.

THE PEOPLE WITH BLUE EYES AND THE PEOPLE WITH BROWN EYES

It seems that some eyes have brown pigment in the cells on the front of the iris, and others have not. This gives us at once two great types of eyes—those which have the brown pigment on the front being more or less brown, and those which have not being more or less blue. There is far more to say than this, of course, because, as everyone knows, there are many different blues and browns, and many eyes which could not be called either. But still we have already learned that a father and mother with genuine blue eyes never have brown-eyed children; on the other hand, if one parent has brown eyes and the other parent has blue eyes, most of the children, at any rate, will have brown eyes.

At present in this country it seems quite plain that blue eyes are rapidly becoming rarer and brown eyes commoner. One of the deeply interesting questions is as to why this is so, and what the consequences will be. Careful study of the iris in thousands of people in all parts of the country, and especially the study of the eyes of children as compared with their parents, will teach us not only a great deal about heredity, as it is called, but will also help us to learn what is really happening, and how far it is true that the blue-eyed strain in our population is dying out and the brown-eyed people surviving.

THE PEOPLE WITH BLUE EYES WHO ARE DISAPPEARING FROM THE WORLD

It is very likely that though the blue-eyed seem less able to bear city life, and the conditions of existence nowadays, they may yet have many valuable qualities, and their slow disappearance threatens to be a great loss to the world, and ought to be thoroughly investigated, and some means found to check it.

Now, if we pass through the door in the iris, we find a beautiful transparent thing called the lens of the eye. It is a genuine lens, just like the lens of an ordinary magnifying glass, and it is of the same shape, convex on both sides. It helps to bend the rays of light entering the eye, just as the cornea did, and it is perfectly transparent. Unlike any lens that any man ever made, this lens, while able to do all that artificial lenses do, can do far more; for it is elastic, and can change its shape as we please.

HOW THE LENS OF THE EYE IS KEPT INSIDE A LITTLE BAG

The lens lies inside a little bag, and that bag has little fibers attached to it all round, which can be pulled upon by tiny slips of muscle inside the eye. When the bag is pulled upon in this way all round, the lens inside it is made flatter. When the muscles stop acting and the pulling ceases, the lens is free to bulge out again if it is perfectly elastic.

It is by this power of the lens that we are enabled to see clearly both at short distances and at long distances. Now, as everyone knows, in the case of an ordinary camera, it is equally necessary to focus the light properly if the picture to be taken is to be sharply defined on the plate; or if we are using a magic lantern, we know that we must focus properly if the picture is to be sharply thrown on the screen. In these cases, and in all other cases where men use artificial lenses—as, for instance, in the microscope and the telescope—the same method of focusing is employed, and that is to alter the distance of the lens, or lenses—for there may be several—from the place where we want the image to fall.

How our eyes focus by changing the shape of their lenses

It is very interesting to discover that in the fishes this method, which men employ in all their instruments, is employed in the eye: the lens has its position shifted nearer to or farther from the retina, or screen, at the back of the eye. But in all the higher types of eye, such as our own, this method is not employed. There is no arrangement for shifting the lens backwards and forwards in order to suit the distance of the particular thing we are looking at. Its distance from the retina is fixed. The method of the higher types of eye is not to alter its position, but to change its shape where it stands. That is why it has to be most perfectly elastic, so that after it has been flattened, by having the bag in which it lies pulled upon, it can spring back perfectly to its rounder shape.

This means that the shape of the eyeball, as a whole, is very important. An eyeball may be long from back to front, and then the lens is far from the retina, or it may be short from back to front, and then the lens is nearer the retina. If the lens be of the same shape in the two cases, one eye or both must certainly not be quite suited to its purpose. Thus, in consequence of the varying shapes of eyeballs, the variations in the curve of the cornea, and the variations in the shape of the lens itself, we find that there are a very large number of people whose eyes are not perfectly suited for all kinds of use.

Near-sightedness has nothing to do with the health of the eye

Nothing is more important than for us to understand, at the very first, that this is not at all a question of the health of the eye. An eye may be healthy or ill, like any other part of the body, but what we are now talking about is simply a question of the mere shape of the eye or certain parts of it. The bending of rays of light is called refraction, and so we usually speak of "errors of refraction" to describe those cases where an eye is near-sighted or far-sighted, or has some defect of that kind.

This has nothing to do with the health of the eye or of any other part of the body, except that, as we shall see, if something is not done, the rest of the body may be affected. We are to look upon the eye for the moment as a kind of optical instrument or machine, and simply to realize that the shape of this optical instrument will affect the rays of light that pass through it, just as in the case of any other optical instrument.

It is very commonly found that the cornea is not quite regularly curved; it bulges more or less in one direction, say, from side to side, than it does in another direction, say, from top to bottom. This means that, if we are looking at a cross, the one limb of it cannot be seen sharply if the other is. As a rule, this defect in the shape of the cornea is so slight that it is not worth bothering about; but often it is worth while to wear glasses which are more curved in one direction than in another—more curved in the direction in which the cornea is less curved, and less curved where the cornea is more curved—so that the little defect is corrected. This particular error of refraction is not nearly so important as those we must now study.

Near-sightedness is what happens when the eyeball is rather too long from back to front. This error of refraction means that the light is focused before it reaches the retina, and when it does reach the retina the picture it makes is rather blurred. Sometimes, also, near-sightedness may be due to the cornea being too much curved, so that it acts as too strong a lens, and the rays of light are focused too soon.

WHY IT IS THAT SOME PEOPLE BECOME NEAR-SIGHTED

Near-sightedness is a very common defect, and is very inconvenient. We can see anything near quite well; the things farther off are blurred. The reason why we see things clearly when they are quite near, and why we therefore always hold a book close to our eyes, is that, when a thing is held close, the image of the object is larger, and so more easily seen.

People who start near-sighted when they are quite young, or who even are far-sighted at first—as most young children are—often become gradually more and more near-sighted until the age of, perhaps, thirty. Most of the people who study this subject are very sure what the cause of this is, only, unfortunately, they do not agree with each other.

Some of them who have not really gone into it properly think that the near-sightedness is a sort of disease of the eye, and is due to over-use of it, bad conditions during childhood, and so forth. Others think that it is a natural change which is bound to happen in any case; and still other people suppose that this increase in near-sightedness is due to the constant use of the eye at short distances.

The truth lies somewhere between the last two opinions; each of them is probably true in part. The eye, like other parts of the body, does undergo natural changes during life, and as it gradually becomes more far-sighted after a certain age, quite apart from anything that is done to it, there is no reason why it may not become more near-sighted during the earlier years.

HOW NEAR-SIGHT IS CAUSED BY USING THE EYE FOR SHORT DISTANCES

On the other hand, we can prove that, when the eye is used for short distances, certain muscles inside it are used in such a way as to tend to make the eyeball longer from back to front, and therefore more near-sighted.

The reason for going carefully into this is that very few people understand the facts, and many doctors even have not properly inquired into them. Young people between the ages of twenty and twenty-five find, very often, that year by year they get rather more near-sighted; perhaps they require to use glasses where formerly they did not need them, and the glasses have to be made stronger or parents find their children require glasses for near-sight.

People are alarmed if they think that all this means a kind of disease of the eye, or if they begin to ask themselves where this is going to stop. That is why everyone should understand that near-sight is not a disease at all; that the changes which go on are natural; that they only go on to a certain point.

More than this, it is certain that we may look upon near-sightedness in our time as a kind of adaptation to our needs—that is to say, in the case of the great majority of people who have to use their eyes at short distances. For such distances the near-sighted eye is just the best that one can have; it lasts splendidly, and does not tire.

NEAR-SIGHTED PEOPLE MAY BECOME FAR-SIGHTED AS THEY GROW OLD

After a certain age, perhaps about forty-five, or later, the eyes, after having remained just as they were for many years, begin slowly to become far-sighted, or less near-sighted, as the case may be. But before we look at this we must return to the case of the child.

Practically all very young children are far-sighted. A certain number of them remain far-sighted as the years go on, and are still far-sighted when they begin to learn to read and write. There is no more disease or ill-health here than there is in the other case, but simply the eyeball is too short from back to front, the cornea is too flat, and so the rays of light are not focused sharply in time, and reach the retina sooner than they should. The retina is too near the lens.

Now, in days that are gone this was no serious matter, because people lived far more natural lives than they do now. They lived much more in the open air. Instead of constantly reading books at a few inches distance, they had to read the book of the distant clouds and mountains; they had to see animals or enemies at great distances, and the use of their eyes for short distances was only occasional.

THE DIFFERENT USES FOR WHICH NATURE HAS FITTED DIFFERENT EYES

When the eye is to be used at long distances, evidently the far-sighted eye has little of which to complain.

But the far-sighted eye is too short from back to front. The rays of light are not focused in time. Now, if such an eye is to be used at short distances, it will be very much strained, because the muscles inside the eye will constantly be trying to change the shape of the lens in order to make the eye focus better; in fact, the far-sighted eye requires to use the muscles inside it in all circumstances. This means that it is liable to get tired, and every far-sighted person knows what it is to get headache and eye-strain from the use of the eyes under conditions which would not be at all inconvenient or disturbing to a near-sighted person.

THE FOOLISHNESS OF MAKING CHILDREN USE THEIR EYES IN A WRONG WAY

In our ignorance and carelessness regarding children, we at present inflict very grave cruelty, and perhaps often injury that is never recovered from, upon large numbers of children everywhere by compelling them to use far-sighted eyes for purposes to which they are not suited.

All over the country, children are straining their eyes at reading and writing, gaining no good, but only harm, from what we do for them, and all they need is a pair of spectacles with rounded convex lenses that will help to focus the rays of light quickly, so that they are brought sharply together by the time they reach the retina at the back of these short eyes. It is the short eye, we must notice, that is far-sighted, and it is the long eye that is near-sighted.

It is just beginning to be discovered how important this subject is, and, now that it is slowly occurring to us that before we start educating a child we must make it fit to be schooled, we may hope that, within a few years from now, no far-sighted child will be allowed to be injured for the lack of spectacles. The relief obtained when proper glasses are employed is quite astonishing.

As we shall readily understand, it is concave lenses that are used in spectacles for the near-sighted eye, and convex lenses that are used in spectacles for the far-sighted eye. We may think this out for ourselves.

As people become elderly, the eye becomes more far-sighted; this change oftenest occurs at some time after forty-five. If the person was near-sighted, he now becomes less so.

Indeed, if we take the whole course of life, there can be no doubt that, under ordinary modern conditions, the near-sighted person is much better off than the far-sighted person, although at first it may not appear to be the case.

The lens of the eye that ceases to be elastic and causes far sight

The far-sightedness of elderly people is due to changes that occur mainly in the lens of the eye. The all-important elasticity of the lens becomes impaired, and it does not bulge, when the pressure of its coat is removed, as readily as it used to do; indeed, it becomes decidedly flatter. In extreme old age the lens loses its elasticity to such an extent that its shape cannot be changed at all.

The commonest sign that the eyes are beginning to show this change is that the person finds it more difficult to read in a dim light. It is very much better to be sensible about this and wear glasses than to try to fight against it. This does no good, and, on the other hand, it may do just the same kind of harm as is done to the far-sighted child that is "educated," as we call it, without having glasses provided for him. The same is true in this case, as has been seen, that people suppose the need for glasses to be a sign of weakness or disease, and think they ought to fight against it.

Now, it is good to fight against weaknesses, and there is not much hope for people who do not; but the weakness is in being too proud to wear glasses or too careless.

Why many great men of the past became blind

In old age, or sometimes before it, the lens of the eye may become opaque. Much the commonest form of this misfortune is found in old age, but there is also a very definite form which may occur in quite young people, and which is known to appear in a regular way in parents and children. Cataract is the name applied to opaqueness of the lens. Its consequence is blindness. The time was, and that quite recently, when there was no remedy for this terrible affliction.

We know that many of the very great men of the past became blind in their old age, and in many cases it was cataract that was the cause. Nowadays science triumphs over this calamity. Thanks to those who have studied the structure of the eye, and thanks to Pasteur and Lister, who have taught us how to keep microbes away from wounds, so that they shall heal easily and painlessly and certainly, it is now possible simply to make a little cut in the eye, then a little cut in the coat of the lens, and then, by a little squeeze, to push the lens out through the cut which was made—and there it lies in the surgeon's hand, looking almost like a little lens of ground glass.

This would probably have to be done to both eyes, though it makes all the difference in the world if it were done to only one eye when both were affected. It is easily done, without pain. The obstacle to the light is now gone, and the light can pour through to the retina; but the rays are not focused, and things cannot be properly seen.

How science is able to give sight to the blind

The remedy is to supply the person with spectacles, with strong convex lenses that take the place of the lenses he has lost. Few operations, so simple and so easy and so certain, do so much for old people, and it would be worth while to study the eye, if only to learn how it is possible, by the application of our knowledge, to give sight to the blind in this way, as is done all over the civilized world many times daily.

In the first picture we see a section of the eyeball between the blind spot and the optic nerve. The middle picture shows the interior of the eyeball with the nerve fibers radiating from the blind spot. In the right hand picture a portion of the retina is highly magnified showing the various layers and the rods and cones.

SEEING COLORS

IN some ways, the most wonderful of all the feats that the eye performs is the seeing of colors, and this subject of color vision, as it is usually called, is also very important from the practical point of view, because in many cases we require to distinguish one color from another; and sometimes the lives of many people may depend upon the certainty with which this is done.

We know that light is a wave motion in the ether. A better way of putting it would be that there are wave motions in the ether which, when they fall upon an eye, give rise to light. Apart from eyes to see, all Nature is in darkness. Neither the eye nor the ether alone can make light, but both are required. We can count the number of vibrations of the ether that affect the eye in a single second.

The smallest number per second that we can see is roughly about four hundred billions. When we see these we get an impression of red. The highest number we can see is roughly about eight hundred billions, and when such vibrations affect our eyes we see a sort of violet.

Now in music a note that is an octave higher than another has exactly twice the number of vibrations in a second; and so we may say that the amount of light that our eyes can see corresponds to one octave, the number of vibrations of the violet being about twice the number of the red. We must clearly remind ourselves once more that just as there are sounds higher and lower in pitch than the eleven octaves or so which we can hear, so there are ether vibrations higher and lower in pitch than the one octave or so that we can see.

We know that our distinguishing of colors depends upon the cones in the retina. We are bound to suppose that in those kinds of eyes where there are only rods, colors cannot be distinguished as they are seen by us; and we begin to understand the immense advantage of having a place in our eyes which is the most sensitive of all, and contains only cones.

From all this it follows that we do not see the colors of objects whose light falls upon the outermost parts of the retina, where there are no cones, or practically none. Also our eyes vary in sensitiveness at different parts of the color scale. At the actual extremes, such as red and blue, we do not notice slight differences in color so sharply as we do in between the extremes, as in the yellow and green.

Colors vary in several ways. For instance, they vary in brightness, as we all know. The brightness of a color depends simply upon the extent to which it excites the brain. We cannot say why one color, because it is that color, should affect the brain more than another; but it is so.

Secondly, we find that colors vary in their hue, or tint, and that depends on the number of vibrations in each second of the ether waves which cause the color.

Thirdly, colors vary very much in what is called purity, or richness. The best types of eyes are very keen to appreciate this quality in colors. A pure color is one which depends upon light of one rate of vibration. The purity of a color is destroyed when it is mixed with other colors, or when it is mixed with white light, which really comes to the same thing, as white light contains all the colors.

THE MYRIADS OF COLORS THAT WE CANNOT SEE AT ALL

Now, quite apart from any question of the eyes, the question of color is simple, because it is exactly the same as the question of the pitch of sounds. Ten vibrations a second means one sound, eleven means another, twelve another, and so on. In the same way, between light made of waves running four hundred billions to the second and light made up of waves running eight hundred billions to the second there is really an infinite number of colors—hundreds of billions of colors. That is all very well, but when it comes to our seeing them we find that the case is different.

If we take white light and pass it through a prism, we get a band of colors called the spectrum, and when we look at it we quite clearly get the impression not of a regular even change of color from one end to the other, but of comparatively few colors to which we give definite names. Of these various colors, which are commonly described as seven, some give us the impression of being mixed, and others of being pure. For instance, what we call orange is mixed; what we are really seeing is a red and a yellow together. Then, again, Prussian blue is not a pure blue, but a mixture of blue and green.

THE THREE PURE COLORS THAT ARE NOT MADE UP OF OTHER COLORS

Now contrast with these colors such a color as crimson red. Nothing will persuade us that that is a mixture of other colors; it is simply red itself. There is also a tone of green which we cannot imagine to be made up of anything else, and the same is true of ultra-marine blue. Probably these are the only three colors of which this can be said. We therefore call red, green, and blue primary colors. The meaning of this is almost always misunderstood.

When we call red, green, and blue primary colors, we are not saying anything about light; we are talking about the way in which the eye sees. Light consists of waves of every rate of vibration, and any one of these rates is as good as another. But the eye, instead of being able to see each of these, has only got within itself means for seeing three of them directly, and these three are red, green and blue.

All the other colors it sees by mixing in various proportions these three kinds of sensation, and that is why we call red, green, and blue primary colors. By mixing these in various ways we can obtain the impression upon the eye of every kind of color that it can see. By mixing red and green rays in various proportions we can get the effect of all the scarlets, oranges, yellows, and yellow-greens; by mixing red and blue rays we can get all the various violets and purples; and by mixing the green and blue rays we can obtain all the various shades of blue-green.

To the three primary colors we have to add a fourth—the gray color which we get from the rods of the retina.

A power that no man understands, by which we see different colors and shades of color

Of course, we now want to know what are the things in the eye which correspond to these various kinds of color sensation or color vision. This can be clearly answered as regards the gray color, for we know that that is due to the rods. We know also that the cones are responsible for the other three kinds of color sensation; but, unfortunately, we can go no further than this, except by guessing. For instance, we do not find that there are three different sorts of cones, nor do we find, as some have supposed, that there are three different parts to each cone—one for each kind of color.

Nor can we show that there are three different kinds of nerves running from the retina to the brain, as Dr. Young supposed a century ago. It may, indeed, be that we are altogether mistaken in looking at the retina for the key to the fact that we see colors by these three sensations.

It may be that the key to the facts is to be found not in the retina at all, but in the gray matter of the vision part of the brain. The fact that a man may be color-blind in one eye is rather against this.

As a rule, color-blindness occurs in both eyes, but there are cases where it is found in one eye only, and that, of course, suggests that it is the eye rather than the brain that is responsible for color vision. Color-blindness is almost always a state of things which exists from birth, and there is no cure for it.

People who cannot see color pictures

About four men out of a hundred, it is said, have one form or other of color-blindness, and about one woman in a hundred. This is by no means the only case in which peculiarities are found more commonly in men than in women. Color-blindness is passed on from parents to children, and we have lately gone far to understand the laws by which it is inherited.

Very rarely we find people who are quite color-blind. The spectrum of sunlight to them appears in shades of gray throughout, being lightest in the position of yellow-green, and darkest at each end. A colored picture to them looks like a photograph or an engraving. If we believe that our three color sensations depend on the presence of three special chemical substances in the retina, then we must suppose that in such cases all these three substances are absent.

Very rare also is "blue-blindness," in which the possibility of blue sensation is absent. Then there is "green-blindness," common, and very important, in which we suppose that the substance corresponding to the green sensation is absent; in such cases bright green is confused with dark red, and a dark green letter on a black background is not seen at all. If we remember that everywhere on railways red is used as the color of danger, while green allows the train to go on, we shall understand how very serious it would be if a railway signalman could not distinguish between a bright green color and a dark red color.

Why railway signals are always red, green, and white

Lastly, there is "red-blindness," also common, which is sometimes called Daltonism, because it was this that Dalton suffered from. Here we suppose that the chemical substance affected by light and corresponding to red sensation is absent from the retina. In these cases light red is confused with dark green, and a dark red letter on a black background is not recognized at all.

Now, as nearly all color-blind men are either red-blind or green-blind, it was suggested that signal colors, instead of being red, green, and white, should be changed; for instance, blue and yellow might be employed. But this does not do. The only convenient colors to use for this purpose are red, green, and white.

It is found that a red glass allows about ten per cent of the light behind it to come through, and a green glass rather more, but a blue glass allows only about four per cent of the light to come through; and yellow does not do, for there are states of the light in which yellow would not be noticed.

It is necessary, then, to test people who are to be expected to recognize lights, and if they are color-blind they must find some other employment.

THE BEST WAY OF FINDING OUT IF WE ARE COLOR-BLIND

Scores of different methods have been invented for detecting color-blindness. The best method, which is generally employed, is the use of colored worsteds, and the person who is being tested is asked to match them. If a green-blind man is handed a skein of pale green worsted, and if he draws from the heap some worsteds which contain no green at all, then he must not be passed; or if a man takes a dark green as a match to a dark red skein, he proves himself to be red-blind, and must therefore be rejected.

HOW WE CAN REST OUR EYES BY LOOKING AT THINGS A LONG WAY OFF

Enough has already been said about spectacles and their importance in correcting the errors of refraction. Here we must note a few points which will help to preserve our eyes, quite apart from the use of spectacles.

When the muscles inside the normal eye are at rest, the shape of the lens and other parts is such that the eye is fitted to see distant objects. There can be no doubt that the first and most natural uses of the eye are for distant and not for near vision. The course of our lives is now such that we use our eyes very much at short distances, and this means the use of the muscles inside them. That is especially true of far-sighted persons, who should, of course, not use their eyes at short distances without glasses. But, apart from that, it is a good rule for all of us to relax our eyes, when we can, by letting them rest upon something which is distant, and so giving the muscles inside them a rest, and lessening the risk of strain.

The best light for vision is daylight—not direct sunlight, but diffused daylight reflected from the sky. When we use artificial light, which we do more and more, it is a safe rule that the nearer it resembles diffused daylight, the better it will be. When we call daylight diffused, what we mean is that it comes from a large surface—the general surface of the sky. What we call a soft light is always one that is diffused in this way.

THE BEST WAY TO LIGHT OUR HOUSES AND TO PAPER OUR ROOMS

In modern buildings the lights themselves should be entirely hidden, and we should see by light reflected from wall or ceiling. Of course, this is expensive, because more light is required; but, though it costs more money, it saves our eyes very much.

Another great fact about diffused daylight is that it is steady, and so should artificial light be. In this respect gas is a great improvement upon candles, and electric light is the best of all.

It has lately been shown by some French students that the different qualities of light affect our eyes in different ways, quite apart from their brightness. The safe rule is that we should, as far as possible, make our artificial light of the same composition as sunlight.

In our houses, if we are wise, we shall have spaces upon which the eyes can rest. This means that we shall think twice before we use wallpapers with marked patterns; this is true especially of bedrooms, because, sooner or later, someone is likely to lie ill in a bedroom, and, whatever healthy people can stand, wallpapers with patterns are a distress and a nightmare to sick people.

The safe rule for reading by day and night

Great stretches of Nature are green. There is probably no color which fatigues the eye less in proportion to its brightness than the green of fresh young leaves. This is good for bedrooms and living rooms alike, Dead white is fatiguing to the eyes, and best avoided. It is excessively foolish to read with the eyes facing a source of light, especially as the light is anything but diffused. We should read with the light behind us, passing over one shoulder or the other—the left shoulder, of course, when we are writing.

So far as children are concerned, we must remember that the great majority of them are far-sighted when they are very young, and that therefore the strain of using their eyes at short distances is even greater for them than for us. The fact that the child is far-sighted ought to be hint enough to us that the best employment for its eyes at early ages is not at short distances. Few and short stretches of reading and writing are all that we ought to require of these young eyes. On the whole, the best work for a small child is its play, and its best play is open-air play with balls and hoops, and so on.

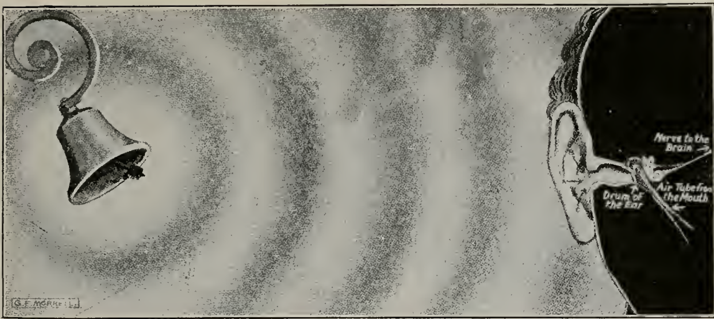
When children are obliged to read, we must remember that they are taking certain risks with their eyes. We should take great care of the lighting arrangements; we must provide glasses if the child is too far-sighted; we should be most careful to use large type deeply printed; and, in any case, the periods of reading should be brief. It is much better to employ some kind of print that makes the letters in very simple shapes.

What the eyes see when reading

When we come to think of the case of a printed page, we shall see that the letters which we distinguish are the only places where the eye does not not see. What we see when we read is not the black, but the white; the letters are not really anything that we see, but gaps in our seeing. As the white occupies a great deal more space than the black, it is evident that our eyes would be much less fatigued if the state of things were reversed, and books were printed in white letters on black paper. If that were so, the eye would be rested everywhere except where there were the letters which it wishes to see.

But reading is not the only use for the eyes, and there are a great many people who think that, while we spend so much time upon reading, we are forgetting to keep our eyes open in other ways.

The time may come when the education of the eye in other matters than reading will always be included in the upbringing of any child. The time for this education, as for every kind of education, is youth, and one great difference between this kind of education of the eye and the kind that has to do with reading and writing is that it is much more suited to the young eye.



This diagram shows us how the sound-waves travel in ever increasing circles and how the outer ear collects the waves as shown by the arrows, A, B, and C, directing them inwards so that they will strike the drum.

THE MARVEL OF HEARING

WE know something of the brain and the spinal cord, which together are called the central nervous system, in the upper part of which the Self of man resides. But when we study the history of the central nervous system, we find that it has been developed from the surface of the body, and this fact in itself argues—as all the other known facts do—that its first business is to receive communications from the outside world.

At the present time these communications take very definite lines, which we call the senses. It is by the senses that we gain all our knowledge of outside things, and it is upon the delicacy of the senses that, in the first place, the high development of the human being depends.

We have reason to believe that this delicacy is, in the main, a matter of the brain itself, rather than of the channels from the world to the brain. But, in any case, it must be distinctly understood that this quality of sensitiveness is so invaluable that all the higher qualities of mankind are built upon it. It is, no doubt, possible to be unduly sensitive—sensitive to a degree that upsets the balance of the mind; but, then, nearly every good thing can be exaggerated.

One of the most horrible consequences of what we at present call education, and of the dull routine through which so many of us are put, is that the beautiful delicacy of sense that enables children to respond to what is new, and to notice the small differences between things, becomes spoiled; the edge is blunted, so that many grown-up people go through the world having lost the sense of appreciating everything which made it such a beautiful, wonderful, and interesting place when they were children. Some day, when we learn more about ourselves, we shall find better ways than those at present adopted in educating and dealing with children, and then we shall get better results.

And now let us go on to study, one by one, our senses, or highways of knowledge. It probably does not matter very much which sense we begin with, for the great principles are the same in every case; only we may begin by noting the names of the various senses, and especially by distinguishing between the senses which communicate with the outer world and certain other senses which do not.

THE SENSES BY WHICH WE KNOW THE OUTER WORLD

The senses which communicate with the outer world are—seeing, hearing, taste, smell, and touch. But nowadays we have learned that it is not sufficient merely to say touch, for there are several senses in the skin besides mere touch. We must at least add the heat sense, the cold sense, and the pain sense to the sense of touch.

In addition to these senses which communicate directly with the outer world, there are other senses by which the brain is informed about the body. Of course, in a way, we may say that, so far as the brain itself is concerned, the body is part of its outer world. These senses come from the organs inside the body, from the muscles and joints, and from certain wonderful little canals in the inner ear, which we shall study later.

HEARING

Now we can take the senses one by one, and we shall begin with hearing. We know that there is a special part of the brain concerned with hearing. If we were to use the word ear for the part of the body that really hears, we should certainly have to say that the real ear is in this part of the brain.

THE REAL EAR IN OUR BRAIN THAT CANNOT HEAR AT ALL

But we are quite certain that sound cannot be heard directly by this real ear in our brain. The part of the brain where we feel touch feels nothing if it is itself touched, and this is true of the senses generally. The brain only responds if the communication is made to it through the proper channel. So what we now have to study is the channel that leads from the outside to the hearing center in the brain. Perhaps the best use of the word ear would be to describe the whole structure, from the surface of the body to the tiny nerve cells where the hearing is actually done.

If we begin at the surface of the body, we find in ourselves and in most of the higher animals a pair of organs projecting from the head, which are the only parts of the organs of hearing that we can see, and which we therefore call the ears, though they are by far the least important part of the whole organ of hearing, especially in ourselves. We have all observed a dog prick up its ears, and so we learn that the real use of the ear—or, as we should properly say, the outer ear—is to catch waves of sound.

It is the general rule that the outer ear is provided with small muscles by which it can be moved in various directions. This serves two purposes. First, it enables the animal to make the most of the sound that comes to it, for the sound-waves are, to a certain extent, gathered up by the outer ear, and so are made rather more intense.

WHY ANIMALS PRICK UP THEIR EARS AT ANY SOUND

But the second great advantage of being able to move the outer ear is that it greatly helps to decide where a sound comes from. This is of great importance to such an animal as the antelope, which hears a sound and fears that it may mean the approach of some danger. We all have opportunities of observing how animals prick up their ears, and we can imagine them saying to themselves: "Where does that sound come from?"

It is very interesting to find in ourselves three little muscles attached to the outer ear, by which it ought to be pulled in various directions. These muscles exactly correspond with those that we find in the lower animals, but in ourselves they have quite fallen out of use. Though they are small, they are still quite capable of moving the ear; but we do not use them. A few people have the power of moving one or both outer ears at will, but there is no record of any human being who ever moved his outer ears when he was straining to hear a sound, or when he was trying to judge the direction of a sound.

We are able still to judge the direction of a sound, but we cannot do so as well as do the lower animals, and the reason, no doubt, is that our outer ears no longer help us. Still, we are able in some degree to compare the intensity of a sound in the two ears, and so we judge more or less where it comes from. If the sound is made at a point equally distant from both ears, we are quite at a loss. A simple and amusing experiment or game will prove this.

An amusing game that teaches us a lesson in science

If someone is blindfolded, we can seat him in a chair and then make little noises, and ask him to judge where they come from. As long as they are on one side he will judge all right; but if we make the noises at the back of his neck, in the middle line of his body, or under his chin, he cannot tell the one from the other.

If we try this experiment on one of those people who can move their ears, we shall find that he does not use his power for this purpose. But one of the lower animals could not possibly be deceived in such a case. By pricking its ears forwards and back, it would in a moment discover in which direction it heard the sound best. It would have no more difficulty in this case than when the sound was on one side. When the sound comes from the side, the animal judges, as we do, mainly by comparing the intensity of sound in the two ears.

The centers of hearing in the brain that compare notes

This seems very simple, and we none of us have any difficulty in doing it; but it is wonderful, all the same, that the two hearing centers should be able to compare notes, so to speak, and when the left hearing center hears loudest we should turn to the right, and when the right hearing center hears loudest we should turn to the left. This is so because most of the nerve-fibers cross the middle line of the body on their way to the brain.

The outer ear is not entirely useless even in ourselves, for if it is all filled up except just at the opening of the canal that runs inwards, we hear less clearly. This experiment can easily be made. It shows us that to some small extent the outer ear is still useful as a sort of ear-trumpet, though vastly inferior to that of most of the lower animals.

From the outer ear there leads a little channel, along which the sound-waves pass. When we cleanse our ears, we cannot and do not wash this channel. It would be a very serious matter if we had to do so, for there would be grave risk of doing harm at its inner end. Yet, as a rule, this channel is kept perfectly clear and open, even though it is never washed. It is lined by tiny glands which produce a sort of wax, and as this wax passes outwards it carries impurities away with it. We think of this wax as a rather unpleasant thing; but in reality it is a beautiful means of cleanliness and protection. At its inner end this canal is closed entirely by a thin, delicate membrane, which is exactly like a drum-head, and it is called the drum membrane or *tympanum*.

THE GREAT IMPORTANCE OF THE DRUM MEMBRANE

This membrane is exceedingly important for the purposes of hearing, and it is a delicate thing. If it is injured, it is, as a rule, injured permanently, and the hearing is affected. It may be injured either from within or from without. Sometimes little children push beads or peas into their ears, and they may do much harm in that way. A child might have reason to regret for its whole life such a foolish action. When anything like a bead has been put into the ear, we should call in the doctor at once and not attempt to get it out ourselves.

This precious drum membrane of the ear is also liable to be injured from within; and earache in children, or indeed in anyone, should not be neglected, because it means, as a rule, more or less of a threat against the health of the ear-drum. We shall understand this better when we see what is on the inner side of the membrane.

If we could see beyond the membrane we should find that it made one of the walls of a little space, or chamber, hollowed out inside one of the bones of the head. This space is known as the middle ear or tympanum. The bone in which it, and also the inner ear, lies is called the petrous bone, from the Greek word for a rock, because it is the hardest bone in the whole body. This is interesting because a hard bone must undoubtedly conduct waves of sound very much better than a softer one.

THE LITTLE TUBE THAT RUNS FROM THE THROAT TO THE EAR

This middle ear is filled with air, and naturally we must ask where the air comes from; the answer is that it comes from the throat. There runs from the back of the throat on each side a little tube which goes to the middle ear and conveys air to it. If we shut the mouth and hold the nose, and then make a sharp movement as if we were sneezing, we can feel something happening in our ears. This is because when we made that movement we opened the little tubes, and drove some air along them into the middle ears. It is a very important thing for the safety and health of the ear, and also for the immediate purposes of hearing, that the air pressure on both sides of the drum of the ear should be the same.

If the air pressure were greater on the outside than the inside of it, the drum membrane would be driven inwards and strained. If any disturbance in the throat or nose closes up these canals, so that air cannot get along them, this is liable to happen.

WHY A COLD IN THE HEAD CAUSES DEAFNESS

Everyone knows that a cold in the head often causes deafness. The reason is that the cold, as we call it, spreads along the tubes that run to the ear. The lining of them becomes swelled up, and so they are closed, and cannot do their duty of keeping the air pressure of the middle ear the same as the air pressure outside. Hence the drum head of the ear is strained and cannot vibrate as it should do to soundwaves, and so we are deaf for the time. In more serious troubles of the nose and throat, such as may happen in scarlet fever, the middle ear may be invaded by the disease, and the drum head may be broken through, and deafness for life may result. It is probably quite fair to say that proper care and treatment from the first could prevent this very unfortunate result in every case.

But the most remarkable thing that we find in the middle ear is a little chain of three tiny bones, much the smallest bones in the body, which are there for a very special purpose. They are called by Latin names, which mean the hammer, the anvil, and the stirrup, and the stirrup especially is exactly like its name. The handle of the hammer lies against the drum membrane; the hammer is jointed to the anvil, and the anvil to the stirrup. The foot of the stirrup rests against a membrane which separates the middle ear from the inner ear, which is the most wonderful place of all.

How the hammer, anvil, and stirrup carry sounds to the inner ear

The business of this chain of bones is to carry sound-waves across the middle ear. That is why it has to be filled with air, for otherwise they could not vibrate freely. Every time a sound-wave causes the drum membrane to vibrate, it sets in motion the hammer bone which is fastened to it, and so the vibration goes on. If the joints between the bones become fixed, the hearing is spoiled in some degree. This may happen in old age.

Lastly, we find two muscles, very tiny but very useful, which pass into the middle ear. They have opposite uses, and we call them into action—though we know nothing about it—according to whether we want to hear a sound more acutely or less acutely. One of them is so arranged that when it pulls it tightens the drum membrane. That makes it vibrate more energetically, and so we hear better. Whenever we strain to hear, we throw this little muscle into action. It is called by doctors the *tensor tympani*, which simply means the stretcher of the drum.

The other muscle has just the opposite effect. It is attached to the stirrup bone in such a way that when it pulls the bone cannot vibrate as well as usual. So when this muscle is in action it interferes with the conduction of sound to the inner ear, and when a noise is unpleasantly loud we throw this muscle into action. It is noticed that in certain cases when there is anything the matter with the nerve that supplies this muscle, loud sounds become unusually painful.

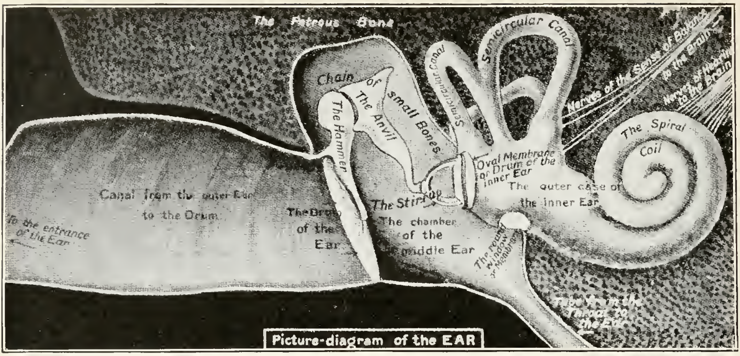
That is all we need say about the middle ear. The more closely we study it, the more wonderful we find it, and we become almost inclined to think that there can be nothing quite so exquisite and perfect in the whole body until we come to study the inner ear, compared with which the middle ear is almost clumsy. The whole purpose of the chain of bones in the middle ear is to carry the sound-waves from the membrane in its outer wall to a similar sort of membrane on its inner wall, on the inside of which is the inner ear. The inner ear is filled with fluid, and every sound that we hear reaches the nerve of hearing by conduction through fluid.

We think of sound as a wave in the air, and that is what it usually is; yet in its last stage, before reaching our nerves, every sound we hear is made of waves in water. This has a special interest if we trace the history of the ear and notice how it has slowly developed from its early stages in the fish, which hears sound-waves conveyed by water.

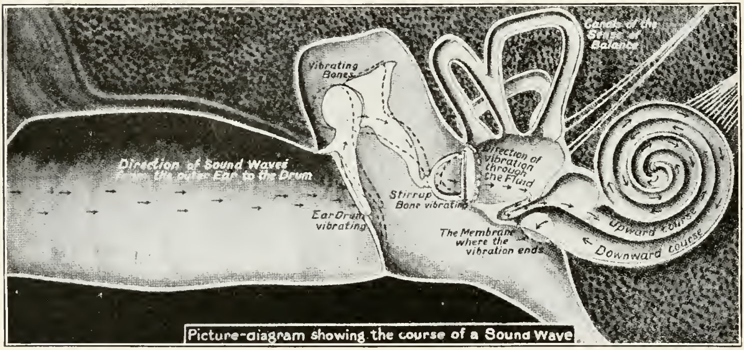
The inner ear that is far more wonderful than the outer ear

The main part of the inner ear is a tiny and very delicate bony structure, rather like a snail's shell. We must understand that all this is filled with fluid. When the foot of the little stirrup bone is thrown into vibration by a sound, it vibrates the membrane to which it is attached, and so there is started a series of rapid little taps to

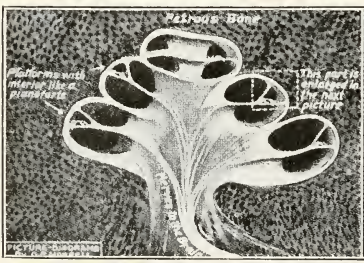
THE WONDERFUL MACHINERY OF OUR EARS



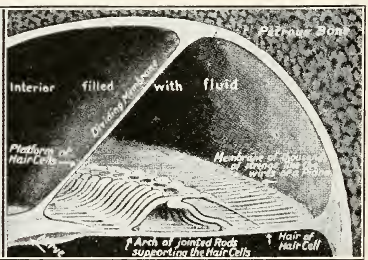
This diagram shows the inside of our ear, from the entrance to the end of the nerve that passes to the brain. The drum is stretched across the end of the canal, and on the other side is the chamber of the middle ear, filled with air that enters from the throat. In this chamber are three small bones, the hammer, the anvil, and the stirrup, the last being fixed to the drum of the inner ear, which is shaped like the coils of a snail's shell.



Here we see a sound wave striking the drum of the ear. The vibration moves the handle of the hammer, which pulls the anvil and pushes the stirrup, as shown by dotted lines, against the drum of the inner ear. Tiny waves of the fluid inside this inner ear pass through a membrane which lines the shell, and, traveling round the coils in the direction of the arrows, communicates its sensation to the nerve, and then returns by another canal.



In this picture the spiral coil is cut through from top to bottom. The little galleries are filled with fluid, and contain very marvelous organs. The part in the dotted square is shown in the next picture enlarged.



Over 3000 little hammers, jointed like those of a piano, support thousands of hair-cells that rest on a membrane. More than 10,000 strings are stretched across, like piano wires, and these convey the wave sensation to the nerve.

the fluid which is lying against the inner side of that membrane, and the waves thus started run right along this spiral coil.

Now, when we carefully examine the inside of this coil with the aid of a microscope, we shall find that we have really come to the essential part of the machinery by which sounds are received. All the rest that we have studied is merely for conducting the sounds. The outer ear, the canal leading from it to the drum, the chain of bones, and the spiral canal filled with fluid, are all mere arrangements for getting the sound in the best possible way to the ends of the nerve of hearing. We may compare all these parts of the ear with all the front parts of the eyeball. These front parts simply serve to carry the light to the curtain at the back of the eye, where the nerve of vision begins or ends, whichever way we care to look at it. And the same is the case with the ear.

THE FIBERS OF THE INNER EAR THAT ARE LIKE PIANO WIRES

But we have not yet actually reached the ends of the nerves of hearing. The little nerve fibers do not hang freely in the fluid of the spiral canal, for there is something in between. We find that along the whole length of the canal, stretched across it from side to side, there is a sort of platform made of delicate fibers. Their number runs into many tens of thousands.

If the spiral were arranged flat, in a straight line — which it doubtless would be but for the fact that a spiral takes up less room in the head —we should see that the fibers are very like a series of piano wires, or like those toy musical instruments made of strips of metal that are struck with little hammers. Many people suppose that there is a meaning in the resemblance of these fibers to a musical instrument.

There are cases where people have been perfectly deaf to one or two notes of the piano, but could hear all the notes above and all the notes below, and in some of these cases it has been found that the piano in the inner ear, so to speak, has been damaged in a way corresponding with the gap in the person's hearing.

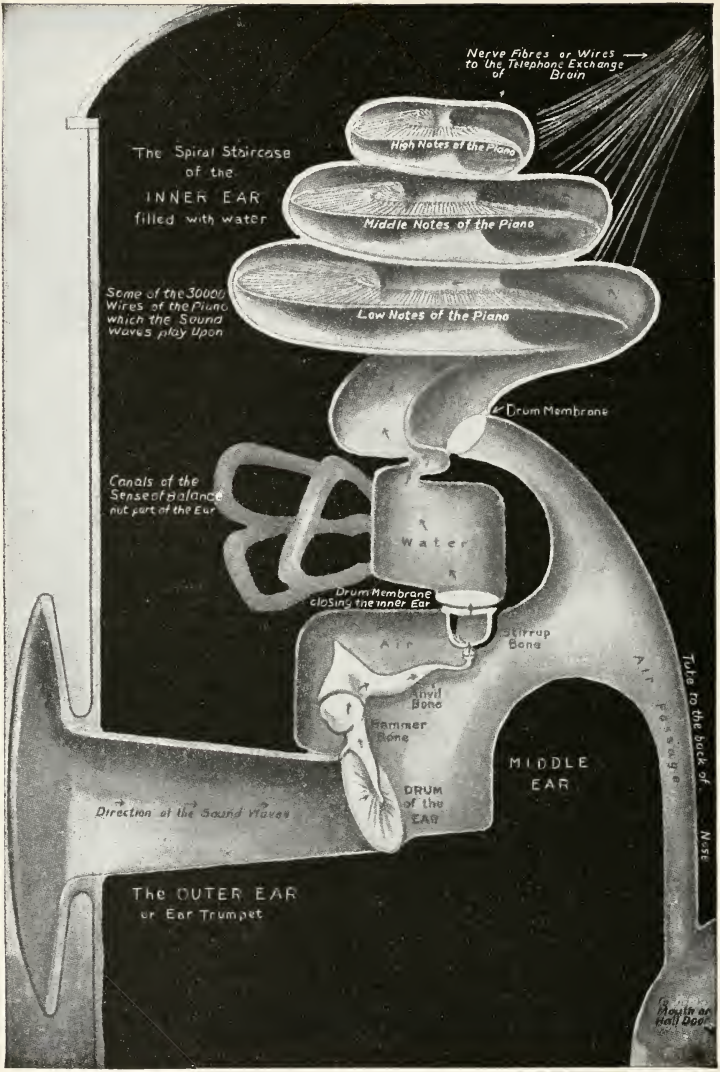
THE LITTLE FINGERS OF THE EAR THAT RECEIVE THE WAVES OF SOUND

Now, upon the whole length of this series of fibers there are perched a number of small but wonderful cells, each of which has a few little things like short hairs sticking out from it, and these little fingers, or hairs, lie in the fluid of the spiral canal. Probably it is these tiny, hair-like fingers that receive the waves of the fluid, and then something happens in the cells. Lastly, if we examine carefully the lower part of each of these cells, we find that the nerve of hearing, which has come to this place from the brain, has sent a few tiny fibers that end at the base of these cells. The fibers do not run into the cells, but the cells are perched upon the ends of the little nerve fibers.

THE JOURNEY OF A SOUND FROM THE OUTSIDE WORLD TO THE BRAIN

Now we have actually traced the sound from the outer world to the ends of the nerve of hearing. We have seen the path of its conduction, sometimes along canals filled with air, sometimes along little bones, then along the canal of fluid, and lastly, through their hairs into certain special cells made for the purpose. Here we come to a point which very few people understand, and as it applies equally to all the senses, we must know it thoroughly. We might suppose that the next thing to happen would be that the sound, having got so far, runs

HOW A SOUND REACHES THE BRAIN



This picture shows the wonderful structure of the ear—the telephone receiver by which we are able to receive messages from outside. Sound-waves of air strike the drum of the ear, which vibrates the bones of the middle ear, and they in turn vibrate the drum of the inner ear. This sets in motion a fluid, and the wave motions are conveyed along the spiral staircase to the wires, or nerves of hearing, and from there to the telephone exchange, or brain.

along the nerves of hearing to the brain. Nothing of the sort occurs.

Hitherto we have been dealing with things that are wonderful and complicated enough—so complicated that what has been said is only a mere outline of the facts—but at this point we have reached something compared with which all the rest is commonplace and simple.

The sound which reached the hair cells of the inner ear does not pass along the nerves of hearing, but it sets up in them a nerve current which runs to the brain. That nerve current is not a sound wave; it is utterly different in every way from a sound wave. But it is that current, and that alone, which excites the hearing cells in the brain, and enables us to say that we hear.

If we examine the nerve of hearing through a powerful microscope, it looks just like any other nerve. But to say merely that it is capable of carrying a nerve current which we translate into sound is not to state half the mystery, for we must consider the infinite variety of sounds that we can hear and distinguish.

THE MANY NERVE-CURRENTS THAT PASS TO THE BRAIN WHEN WE HEAR MUSIC

What must be the number and delicacy and variety of the nerve currents passing along these nerves of hearing when a great musician conducts a big orchestra, and can hear every instrument separately, and know whether it is in tune or not! How delicate must be the varieties of current that are possible when we remember that it is scarcely possible for us to mistake the voice of one friend for that of another.

So long as we confine ourselves to the study of the inner ear, and see the tens of thousands of fibers of different lengths, and the hundreds of thousands of hair cells which it contains, we are not so much puzzled, because here is something which seems to correspond with the sense of hearing.

There ought to be the power of noticing slight differences in sounds by means of an organ so complicated as the inner ear is. But the inner ear would not be of the least use without the nerve of hearing, and every one of these tiny differences in sounds means a tiny difference in the something that runs along the little white threads that make up this nerve.

THE GREAT MARVEL OF NERVE-CURRENTS THAT VERY FEW PEOPLE THINK ABOUT

Language cannot say how wonderful these things appear to those who really think about them; and it is a great pity that so many of us should go through the world, hearing, seeing, and moving, and yet never giving a thought to these marvels upon which our lives depend.

The fact that nerve currents, and not sound currents, travel along the nerve of hearing is a general truth of all the senses. It is not light that travels along the nerve of vision. The place in the brain where we see is enveloped, and lives always in utter darkness; no light ever reaches it. What reaches it is the nerve currents from the nerves of vision. All that the light does in entering our eyes is to do something which starts those nerve currents in the ends of the nerve of vision.

And all that sound does in entering our ears is to start certain nerve currents in the ends of the nerve of hearing. When we study the variety of sensations that are possible for us, we see that a nerve current, though we talk about it so easily, must be nearly the most complicated and wonderful thing in the world, compared with which the waves of sound, or light, or electricity, must be considered quite simple.

HOW THE BODY IS HELD IN BALANCE

THE inner ear would be quite sufficient to make the bone that contains it the most wonderful in the body. We know that that bone is the hardest in the body; and this is necessary not only because it forms part of the base of the skull and should be strong, but also, we suppose, because a hard bone conducts sound waves better than a more loosely-built one.

We must understand that the important thing in hearing is for sound waves somehow or other to get to the hair cells. Much the best way is through the fine series of structures about which we have read; but though they are very useful, and though we cannot hear anything like so well without them, they are not necessary.

From the teeth, or from the bones of the head in general, sound waves can be conducted—and, of course, are conducted, whenever we hear—which are conveyed very well by the dense bone that contains the inner ear, and so get to its hair cells. Sound waves reaching the ear in this way contribute to the keenness of our hearing, but of course they cannot compare for effectiveness with those that travel along the wonderful path made for the special purpose of hearing.

But there is another reason why the bone that contains the inner ear is of very great importance and interest. It also contains another organ of a wholly distinct sense, which lies close beside the inner ear, and is, indeed, in more or less direct communication with it. For many years it was supposed that this organ was part of the inner ear, and was concerned with hearing. We now know that it has nothing to do with hearing.

The mistake was made more natural by the fact that one and the same nerv seems to run from the brain to both parts—as they were supposed to be—of the inner ear. In point of fact, what looks like one nerve, and is still called one nerve, is two wholly distinct nerves, as we can readily prove if we trace the course of the fibers towards the brain.

We find that the fibers which have come from the real inner ear all run to a certain part of the brain, the business of which is hearing. But we find that the fibers which have come from this other organ all run to an entirely different part of the brain which has nothing to do with hearing at all.

In fact, what we are here dealing with is the sense of balance, and it is probably more or less of an accident that its machinery happens to be such a close neighbor to that of the sense of hearing.

A LITTLE-KNOWN PART OF OUR BODY THAT HELPS US TO STAND

This sense of balance is, in a way, a sense that tells us about the outside world, like hearing or vision; because it does tell us where the outside world is in relation to our bodies. But it is quite unlike the senses we know so well, as it is not arranged to receive anything from the outside world at all, and so, unlike the eye or ear, it has no connection with the surface of the body. We may say that this is one of the senses which tells the brain about the body, rather than about the world outside the body.

Before we study the organ of this sense, we must notice, in the first place, that it is helped by other means. We do not entirely depend for our balance upon the organs of balance in the base of the skull, though we certainly cannot balance ourselves without their assistance. When we stand, for instance—and standing is a very much more difficult matter than we usually suppose—our power of balance is greatly helped by the feelings we get from the soles of our feet. If something is painted on to the soles of our feet so that the skin there can no longer feel, or in cases of illness which have the same result, we cannot stand so easily as we usually do.

But the sense of balance is also helped by the eyes. As long as the eyes are open, even a person who is not helped by the soles of his feet may balance himself; or, with his eyes shut, he may yet balance himself if he stands with his feet far apart; but if he puts his heels together, and shuts his eyes, he will probably topple over on the ground.

THE GREAT USE OF THE EYES IN BALANCING THE BODY

People, however, can stand with their heels together, and with their eyes shut, thus doing without the assistance of sight, if the organs of balance in the skull are all right, and if guidance is also coming to the brain from the soles of the feet, and also from the muscles and joints of the legs. If we set ourselves the task of balancing on a very narrow plank, or, still more difficult, on a tight-rope, then our eyes become more useful, and, unless we are very skilful indeed, they are quite necessary.

Everyone knows how the tight-rope walker keeps his eyes steadily fixed on a certain point, and so greatly helps himself. If he is very skilful, he may walk on the tight-rope even though he bandages his eyes; but this is far more difficult. However, the eyes and the feelings from the skin and joints and muscles are all unimportant compared with the guidance we get from the special organs of balance, and no one was ever yet able to stand or walk on the ground, much less on a tight-rope, in whom these organs were not working properly. Now we must learn what they consist of.

In the hard bone that contains the inner ear, and close to the inner ear—on each side of the head, of course—we find this organ of balance. It consists of three tiny tubes, in shape like half a circle.

THE SIX LITTLE TUBES WHICH TELL THE BRAIN OUR MOVEMENTS

The proper name for a half circle is a semi-circle, just as half a tone is a semi-tone, and the corresponding adjective is, of course, semi-circular; not a difficult word if we know how it is made up. The proper name for these tubes, then, is the semi-circular canals, and of these the head of every human being and of all the higher animals contains six, three on each side. They are all filled with fluid.

Just as the nerve of vision runs to the eye and the nerve of hearing to the ear, so the nerve of balance runs to the semi-circular canals. The ends of the nerve—that is to say, the ends of the countless nerve-fibers which make the nerve—lie close to the fluid that fills the canals, and if that fluid moves, or if the pressure on it changes in any direction, the nerve-fibers know about it and tell the brain our movements.

Now let us look at an ordinary child's block, which we call a cube. If we want to measure it, we find that it can be measured in three directions—from top to bottom, from side to side, and from back to front. We may pick up any solid thing and we find the same is true of it. We may want to measure a room, and we find again that the same is true; we must measure the floor in both directions, and we must also measure the height of one of the walls.

A BLINDFOLDED MAN'S WALK ACROSS NIAGARA

One of the most marvelous feats of balancing ever performed was the crossing of Niagara Falls by Blondin, who walked across the Falls on a tight-rope, blindfolded. The eyes are very helpful in enabling us to keep our balance, but they are not really essential, and Blondin was able to walk over Niagara with his eyes covered, being aided by the six little canals in his head, which are the organs of balance, as described.

In general terms, space has three directions—or dimensions, to give the usual word—and when we move our head it must move in one or more of those three directions. We may nod our head, or we may shake our head, or we may raise it up and down. All the possible movements of the head are either in one of these directions or in a combination of two or all three of them. Now, the business of the organ of balance is to acquaint the brain with every possible movement of the head, and it must therefore be so constructed that all possible movements shall duly register themselves in it.

This is done in the most exquisite way by the provision of three canals on each side of the head, these three canals being arranged in correspondence with the three dimensions, or directions, of space. One canal lies on its side or is horizontal; and the other two are upright, but at right angles to each other. As there is an organ of balance on each side of the head, we may think of the canals in pairs, and there is no doubt that they act in pairs. For instance, the horizontal canal on each side of the head acts with its fellow when we shake the head, or when we spin round, as we do in dancing.

THE MOVING FLUID IN THE SIX LITTLE CANALS IN OUR HEADS

The consequence of this arrangement is that every possible movement of the head has a strictly corresponding effect upon the fluid inside one or more pairs of these six canals, and the center of balance in the brain is informed. This center of balance probably exists in the cerebellum, or little brain. Sometimes we have an illness in which the organ of balance is thrown out of action, and just as a person whose eyes are injured cannot see, so those in whom the organs of balance are injured cannot balance. They suffer from persistent giddiness.

It has also been proved that where the injury affects only certain of the canals, the giddiness corresponds to the direction of the particular canal or canals in question. If it is only the horizontal canals that are thrown out of action, then we shall be all right so far as nodding the head is concerned, but directly we start shaking it, we shall become giddy, and, if we do not receive support, topple over.

The history of the semi-circular canals is deeply interesting. The lowest kind of creature with a backbone, as we know, is the fish, and we find in it no trace of these canals. Now, the fish is very clever at balancing itself, and shows no signs of giddiness; but probably we can explain why the fish manages so well without any semi-circular canals, if we remember how great the pressure of water is upon the surface of the fish, and therefore how much more information the fish must get from its skin than we are able to get from ours.

HOW BIRDS ARE ABLE TO FLY WITHOUT TUMBLING OVER

As we ascend the scale of backboned animals, we gradually find the appearance of these semi-circular canals, though they do not all appear at once. If our statements as to their use are correct, we should expect to find them most beautifully and perfectly developed in birds, which could not succeed in flying without a perfect sense of balance. In flying, the bird gains little from the feet and legs, as we do in the very much simpler business of standing or walking; and therefore its need of special organs of balance is all the greater.

So we find the semi-circular canals at their very best in birds, and we know also that, just as in our own case, if the canals are thrown out of action, the bird's power of balance is destroyed, and in flying it will make mistakes and show peculiarities corresponding to the particular defect in its organ of balance. It is probable that in this way we can explain the peculiarity of what are called "tumbler" pigeons.

It used at one time to be thought, before these newer facts were discovered, that the semi-circular canals must have something to do with hearing; and we can understand how natural this idea was, seeing that the canals look as if they were part of the inner ear, and their nerve looks as if it were a part of the nerve of hearing.

THE LITTLE ORGANS IN OUR EARS THAT HAVE NOTHING TO DO WITH HEARING

The idea used to be that probably we somehow judge of the direction of sound by means of these semi-circular canals. No one could look at their odd arrangement without feeling that their business had something to do with direction. But we now know that their business is with the direction in which the head moves, and not with the direction of sound. It is much more important to know what the head is doing than to know where sound comes from, and, in any case, by having external ears that can be moved, a creature can easily enough judge of the direction of sound without any special machinery inside its head. If we human beings are not so well off in this respect, it is because we have lost the power of moving our outer ears like the animals.

THE FISH'S GILLS, UPON WHICH MANY PRECIOUS STRUCTURES ARE BUILT UP

We have lost this power that the animals have, but we have gained many things that the animals have not. In the very lowest vertebrate animals, such fishes, we find, instead of lungs, have what are called gills. To these the blood runs, as it runs to our lungs, and in them it comes in close relation with the oxygen dissolved in the water, just as in our lungs the blood comes in close relation to the oxygen of the air. The gills have to be supported on something, and so we find in the fish five gill-arches, with slits between them called gill-slits.

HOW THE SWIM-BLADDER OF THE FISH BECAME THE LUNG OF THE MAMMAL

We can never tell what uses nature will turn a thing to, and the history of life upon this earth proves over and over again that organs which would appear to have lost all their use, and of which nothing could be made, may be turned to new and utterly different purposes, rather than be wasted. Nature took the swim-bladder, which used to be filled with air, and helped the fish to swim at the level it liked, and when the creature no longer swam under the surface at all, she made it into a lung. Thus nature had gill-slits and gill-arches thrown on to her hands with their occupation gone. By long and careful study of many animals we have been able to trace what happens to each of these; and it is one of nature's great triumphs in the development of the bodies of the higher animals that she has been able to do with these apparently useless things.

Out of them has been made the whole of the semi-circular canals. Thus nature has provided for the balance of the bird out of the organs which helped the fish to breathe. From these organs, also, she has made the whole of the ear, including the little bones in the middle ear, and all the wonderful structure of the inner ear. As if this were not enough, she has also made out of the gill-arches an organ no less new and wonderful than the voice-box, or larynx, by which we speak and sing.

THE VOICE AND ITS MECHANISM

IT IS much better, for two good reasons, that we should go on to study the larynx. First, we should do this because then we shall be studying together the various organs that have been developed in the higher animals from the gill-arches of the fish; and, secondly, we should do so because it is well to study the means by which we produce sounds, after studying the means by which we hear them.

We all know something, at least, about the larynx, because we have all seen the front part of it pushing the skin forward and sometimes moving up and down. There is a foolish notion that this is the apple which Adam swallowed, and which stuck in his throat, and so it is sometimes called Adam's apple. A larynx, or voice-box, similar to ours is to be found in all the higher animals, and, as we know, it is simply a stringed musical instrument. In the case of the birds, many of which have such beautiful voices, there is besides this stringed instrument another, which is practically an organ pipe. But, in all its forms, and whether with or without this organ pipe, the larynx is evolved from one of the gill-arches of the fish.

This voice-box, of course, is not only concerned with speaking and singing; it has important duties to perform every moment of our lives, because it is the channel of the breath of life. Further, owing to the manner in which the lungs have been developed in long-past ages, it has so occurred that the opening from the throat to the voice-box lies in front of the opening from the throat to the gullet.

Only the study of the way in which living things have developed one from another can enable us to see any meaning in this arrangement, which, as we know, makes it necessary for everything we swallow, whether liquid or solid, to be thrown over the opening to the larynx without entering it. There is thus placed upon the larynx another duty besides that of producing sound, and that of attending to our breathing, for it has to protect the air passages every time we swallow. This organ is made of pieces of what is called cartilage. Our ordinary name is gristle, and we may describe it as something which is half way towards bone.

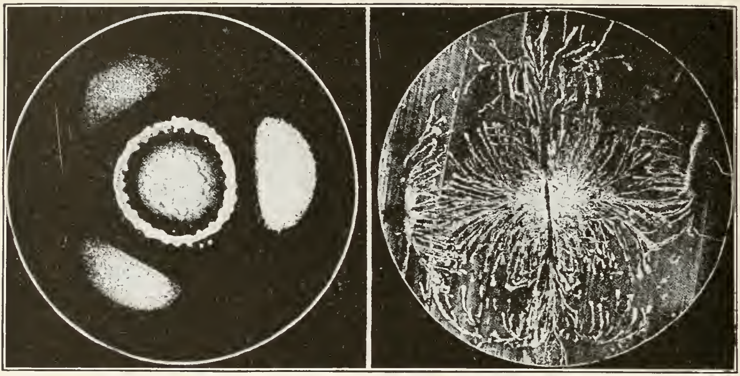
THE NARROW CHANNEL THROUGH WHICH PASSES ALL THE BREATH OF LIFE

In old age the cartilages of the larynx get to be not exactly bony, but more chalky and rigid than they are in youth; and this, probably, is one of the reasons why most people with sensitive ears can readily distinguish a young voice from an old voice.

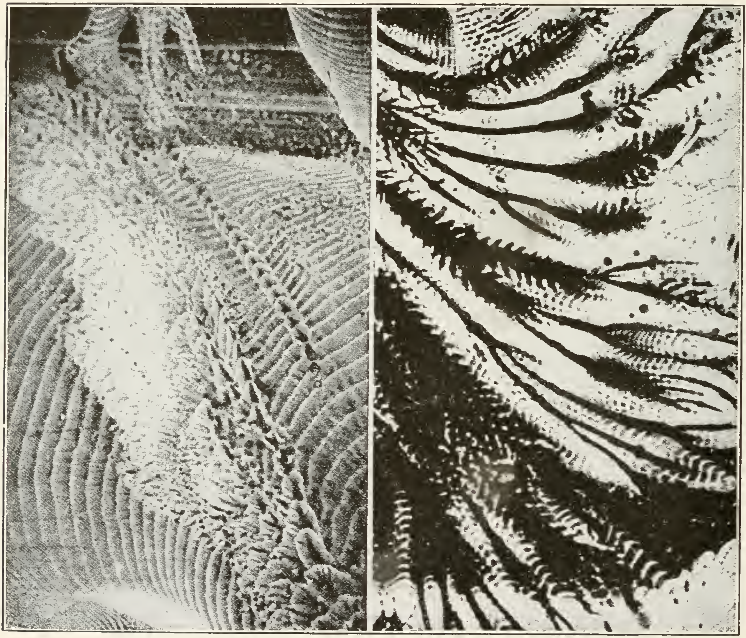
The business of the larynx is to support and control the action of two tiny cords or strings called the vocal cords; that is to say, the voice cords. The picture given in connection with this article shows what the vocal cords look like when they are seen from above by means of a bright little mirror held at the back of the throat. We see that the vocal cords have a free edge towards the middle, and that from it they pass outwards to the sides of the larynx.

All the air by which we live passes through the narrow space between the vocal cords. The arrangements by which they can be put together or separated are quite simple. They part every time we breathe in, and when we choke and cannot breathe in, it is because the vocal cords are not parting as they should. But if the cords are to produce voice, they

PICTURES DRAWN BY THE HUMAN VOICE



No artist drew these designs. A thin sheet of india-rubber was stretched over a vessel like a cup which had a spout at the side. Some light powder was then thrown upon the rubber covering, and when someone sang into the spout, the powder formed itself into the design of the picture on the left. The right-hand picture, looking like a frosted window, was drawn in the same way, but, instead of powder, moist paint was put on the rubber covering.



To obtain the left-hand picture, a sheet of glass was coated with paint and put over the cup, with the paint resting on the rubber covering. Then, as the spout was sung into, the glass was moved round, and this beautiful design appeared. The picture on the right—something like a fern-leaf—was made by singing louder and having moister paint on the glass. The cup with a spout or tube is called an eidophone, which means "form of the voice."

must be able to do much more than this. It must be possible to hold them tightly stretched, so that when air is forced against them they will vibrate. Nor is this all, for it must be possible to stretch them in different degrees. As we shall learn when we come to study sound, the pitch—the shrillness or the lowness—of a musical note produced by anything trembling depends upon a number of things, such as its weight, its length, and its tightness.

The wonderful musical instrument with one string

Now, in the case of a piano, when we want to produce notes of different pitch, we have a number of strings of different lengths laid side by side, so that we can strike the one that gives out the required note. Also, we can have some of them made of much heavier material than others. In the case of the violin, it is possible to have only very few strings, but we can produce all the notes we want by stopping the strings with our fingers, so that the length of string that is free to vibrate can be altered as we please; and the strings are made of different weight and thickness.

But in the larynx there are only two strings, and these always act together, it being impossible to produce voice with one of them; moreover, they are of the same weight and length. Outside the human body, a musical instrument that had practically only one string, and that could not be stopped at different points like a violin string, would not be able to produce much variety of pitch. The only possible way of getting any variety would be to have some means of varying its tightness. It is probably correct to say that there is no material other than that made by life that can be tightened in such different degrees as the needs of music demand, without permanent injury to the strings.

The marvelous power that a good singer has over the human voice

But though our vocal cords have only the one possibility of varying pitch, due to the fact that they can be tightened in different degree, with this one means they triumph. A good singer can produce all the notes in a range of two octaves, and many singers are able to exceed this compass considerably. Outside the body there is no parallel to this. It is interesting, therefore, to know of what the vocal cords are made, so that they can stand such varying degrees of tightness, within a few seconds, without injury. They are simply made of fibers of what we call elastic tissue, such as is found in various parts of the body wherever it is needed. But an ordinary piece of elastic is rubbish compared with the elastic tissue made by the body.

How the vocal cords are tightened to produce different sounds

The next question is—How is their tightness varied? In front, just behind the part of the voice-box that we see from outside, the cords are fixed to the largest cartilage of the larynx, but, behind, each of them is fixed to a tiny little knob of cartilage which is delicately jointed to the part that it rests on, so that it can be tilted in several directions.

What really happens when we sing is that these little knobs of cartilage are tilted backwards so that the cords are made tighter when our voice ascends in pitch, and are tilted forwards so that the cords are made slacker when our voice falls in pitch.

When a singer is producing one of his highest notes, the cords have to be so tight as to vibrate four times as often in every second as when he is producing one of his lowest notes.

Thus, in the whole range of nature, there is scarcely anything more perfectly delicate than the control which a singer has over this tiny little machine to produce such results.

WHY THE HUMAN VOICE IS MUCH MORE MARVELOUS THAN A PIANO

Nor must we suppose that the singer is merely limited to the number of notes that there are on the piano in two octaves. Pianos vary in pitch, as we know, and a singer can tune his voice to the pitch of any piano he sings with. Skilful singers can produce several tones, even as many as eleven, between two notes that are next to each other on the piano.

As we have said, all this depends on the tightness of the cords, and the tightness depends on the strength with which certain tiny slips of muscle pull upon the cartilages to which the cords are attached; and that depends upon the force of the nerve current sent to the nerves through these muscles from certain nerve cells in the brain. The place, therefore, where the unrivaled delicacy of this machine really exists is the nerve center in the brain.

As everyone knows who has tried to read a song he was not sure of, or as anyone may observe who watches a child learning to sing, it is one thing to have all the machinery for producing a note that is easily within the range of our voice, and it is quite another thing to be able to produce that note when we want to. There are two stages of difficulty here, and the second is marvelous beyond anything we have yet described. The first of these is where we simply imitate a note we hear.

This is quite wonderful enough, for it means the beautiful working together of the cells in the hearing center of the brain with the cells of that part of the brain which gives orders to the muscles of the voice-box.

THE MYSTERY OF THE WRITING AND SINGING OF MUSIC

But now take the second case, where a singer sings aloud the notes of a piece of music that he has never seen before. What is it that he imitates now? What is it that guides him? We can only say that the singer imitates, or realizes, his idea of a certain sound that he has in his mind, but what and where the idea really is, and how the singer can do what he does, no one can say, for we are here in the realm of the mind—the most mysterious of all things, and it baffles us utterly.

Lastly, we have the case of the composer sitting down with a pencil and a sheet of paper, and creating music "out of his head" for other people to sing and play. Some of the greatest music ever written—music which has made miserable people happy, and cowardly people brave, and frivolous people solemn, and will do so to the end of time—was written by a man named Beethoven many years after he had become stone deaf. He never heard a note of the greatest and most wonderful part of the music that he wrote; and yet, in his mind's ear, he heard it better than anyone has ever heard it since, or he could not have created it.

In these pictures we see the positions taken by the tongue and lips when different vowels are pronounced. The position of the larynx remains the same, the different sounds being produced by the changed position of the resonators, or cavities above the larynx. The vowels shown are A, as in father, E, and U.

TALKING AND SINGING

WE know how the larynx, or voice box, the musical instrument which we all possess, produces notes of any particular pitch that we desire. But though singing is very delightful and pleasing, and though many books might be written upon the voice box and its use in singing, speaking is really much more important than singing, and therefore it is necessary to study speaking from the point of view of the machinery by which it is done.

We have already learned about the wonderful center in the brain where words and the meaning of them are stored, and we understand that everything else depends upon the .orders given there, but now we must go on to study the machinery by which those orders are carried out. The voice box is, of course, the central part of this machinery, but it is not all; and, indeed, everyone knows, who has whispered, that it is possible to speak without the voice box at all.

There is one point which has been greatly discussed by many thinkers, and which we must mention first. We know that we ourselves both speak and sing, and when we observe the birds, we find that they sing, but do not speak. The question is: Did singing or speaking come first? And there is a difference of opinion on this matter. A great Frenchman, named Diderot, at the end of the eighteenth century, and Herbert Spencer, many years after, supposed that singing came later than speaking. Their argument was that, after learning merely to speak, the time came when men wanted to make their speech more effective and thrilling and moving, and so they sang the words instead of only speaking them. So on this theory speech came first, and song is a sort of speech with more effect added to it by the addition of music.

But against these great opinions there is another great opinion—that of Charles Darwin. For many years he studied the expressions of feeling in man and in the lower animals. He found, as he thought, that many of the lower animals, especially the birds, sing of set purpose, so to speak, and perhaps sing very beautifully. He supposed that the special reason for the song of animals was to call each other and to please each other. Now, on this view, song came first and speech afterwards with man, and that is what Darwin maintained.

This is a subject which one writer has specially tried to study, and what he thinks is that in the case of mankind speech and song have arisen together. They are really two varieties of the same thing, which is expression by means of the voice. The argument of Diderot and Spencer that speech came first and song afterwards is, not supported by the fact that when we observe the growth of very small children, we can see the beginnings of speech and of singing growing up at one and the same time in them; nor is there any reason at all why this should not be the case. However this may be—and it is at least an interesting subject to think about—let us now go on to study what happens when we speak.

Why it is that we use different notes in speaking

First of all, let us discover what is the difference between singing and speaking. In both cases we produce sounds by means of the voice box, except in whispering; in both cases these sounds are musical notes—that is to say, the waves which form them are regular; in both cases there are changes of pitch.

No one speaks with his voice all the time on the same note, even in the shortest sentence. We raise the voice sometimes, we lower it at other times, as we go along, and we convey a great deal by the way in which we do this; so much so, that children or foreigners, who do not understand the words we are saying, may learn a great deal from the pitch of the notes we speak in.

Even a dog or a horse will learn much from our voices in the same way. If anyone doubts that we use a number of different notes when we speak, let him get someone to say a sentence all on the same note, without raising his voice or lowering it. The Greek word for one is monos, and so, when something is spoken or sung all on the same note, we say that it is a monotone, and thus we get the word monotonous.

How we are able to put color into our voices

We could scarcely live with anyone who spoke in a really monotonous voice. Also, we use different loudnesses when we speak, and, apart from the actual note we are speaking on, we use d'fferent kinds of what is often called color in our voices. We speak to a child in a more tender tone than we speak to a car conductor, though we may speak more loudly to the child than to him. There are many different shades of expression which we can put into the same words spoken on the same notes and with the same loudness.

Now, the reason why it has been necessary to go so carefully into this is that we want to find out the difference between speaking and singing, and the first thing we find is that in all real points the singer does no more than the speaker does. He uses a variety of notes, he uses a variety of force, he uses a variety of colors. Both singers and speakers use a variety of rhythm and speed.

But, nevertheless, no one will say that speaking and singing are the same, and everyone knows what it is to hear someone speaking in a singsong voice. There is a common English word which has a very interesting history that bears on this point. It is the word cant. We say that a thing is cant or that a person is canting when we mean that he is professing high ideas that he does not really believe. The word comes from the Latin canto, I sing. Cant and chant are really the same word, and we might as well say that a person is chanting as that he is canting.

What happens when anybody speaks in a sing-song way

The explanation is that at a very interesting time in history there were certain people, having very strict views on many things, who had the habit of speaking in a sing-song way. When they spoke they rather chanted. Their enemies said that they did not believe what they professed, and so the word cant, which really means singing, came to mean insincerity.

Now let us ask what it is that happens when a person, who was speaking in the ordinary way, speaks in a sing-song way, or actually sings. What happens is that he now produces notes which have fixed regular intervals between them, like the notes on a piano. When we speak we do not use the fixed musical intervals of pitch, but slide the voice up and down, without taking any notice of the fixed intervals of music at all. It is true, also, that as a rule, when we speak, we may keep our voice within the limits of, perhaps, half an octave or less, while when we sing we may range over a couple of octaves or more. But though this is evident directly we think about it, it is not the real difference between speaking and singing, which is that in singing we use only notes with fixed intervals between them, while in speaking we let our voice rest just where we please. If we think of a violin, we can, perhaps, understand this better. A player gets definite notes on the violin, such as the notes that are on the piano, by placing his fingers firmly on the strings at fixed intervals.

One of the great problems for the player is to get his fingers always at exactly the right places on the string. Now, when we sing, it is as if we were using just those intervals, only that, as we have seen, we do not get our notes by the violin player's method, but by tightening or loosening our vocal cords. If we do not use these intervals when we sing, people say that we are singing out of tune, and go out of the room as quickly as possible, and we are only asked to sing by people who have never heard us sing before.

Why different people have different kinds of voices

But the violinist can also move his bow across a string and make it sound, while, at the same time, instead of stopping the string at certain intervals, he slides a finger right along the string. So, as the string gets gradually longer or shorter, he produces a series of notes—thousands in number really—which cannot be imitated on the piano. Now, our vocal cords can have any tightness or slackness, and so it is possible for us to pitch our voices, as we speak, at any point we like, just as if the violinist were to stop moving his finger at any point along the string of his instrument.

One of the great differences between voices is in the person's choice of the notes he speaks on. It might be supposed that if one did not sing, it would be all the same what notes one spoke on; but we all know that there are people to whose speaking it is a real musical delight to listen. It may be noticed sometimes that well-trained singers who sing quite well, but are not really musical, speak unmusically, and everyone knows cases of people who do not sing at all, but who have most beautiful speaking voices. To people with sensitive ears there is scarcely a greater delight in life than to be surrounded by people with beautiful speaking voices, and one of the reasons why we ought to study this question here is that we are running a grave risk today of losing the beauty of our speaking voices, and for several reasons.

THE GREAT CARE THAT SHOULD BE TAKEN OF THE VOICE IN LARGE FAMILIES

One reason is simply the way in which we crowd together. It is probably safe to say that more pleasant speaking voices come from small families than from large ones. If we are one of twelve children, and we want to be heard—well, we are rather apt to discover which is the most piercing tone we can produce, and then, perhaps, we use that all the rest of our life. People should take great care of their children's voices in this respect, especially when there are many children, and they all want to speak at once and be heard.

Perhaps it would be a good rule to listen first to the one who spoke most nicely and quietly.

A person who speaks in a high-pitched, harsh tone—as if he scarcely expected to be heard, but meant to have a try—tells us something about himself and his surroundings. Contrast that with the woman who speaks in a voice rather low-pitched, quiet, and musical. In so doing, she almost tells us—does she not—that she is accustomed to live in surroundings of peace and quiet where people do not interrupt each other, where no one shouts, and that she, indeed, would rather not be heard at all than make distressing noises. In perhaps the most heart-breaking scene he ever wrote, Shakespeare makes poor King Lear say of his daughter Cordelia: "Her voice was ever soft, gentle, and low, an excellent thing in woman."

To some children who read these words, this may appear not very important; but if we wait until we are unhappy, or until we are ill, or until we have to live with one and the same person all our life, then we shall find out what a difference it makes to be surrounded by people with soft speaking voices.

THE GREAT VALUE OF CULTIVATING A SOFT AND GENTLE VOICE

There are doctors and there are nurses who are worth far more than others are to their patients, not because they are more skilful or more conscientious, but because they have the kind of voice that often goes halfway to making a sick person well.

Every year hundreds of thousands of dollars are spent on singing lessons and on listening to singers. That is all very well in its way, but it is a curious thing that so few of us trouble at all about speaking lessons or about making any conscious effort at all to speak nicely. Parents will cheerfully spend large sums of money on having their children taught to sing, and will, at the same time, allow those children to talk regularly in a way which would distress any dog.

We already know upon what the pitch of the voice depends, and we know, too, that a tone of any given pitch may have different shades of color, or quality. This is, at first, not easy to understand, but it becomes clear as we study sound.

WHY WE CAN SING THE DIFFERENT VOWELS ON THE SAME NOTE

The fact is, that when we speak or sing on a given note, that note is really a mixture of a large number of notes. The lowest of these is the principal one, and is the one we hear best. But mixed up with it there are several others, called over-tones, which color it and give it its quality.

Now, we all know that it is possible to speak or sing any of the vowels on the same note. When we read this, we should quietly say or sing *a, e, i, o, u* to ourselves on the same note—and, of course, these are by no means all the vowel sounds that there are. Now, if these are all on the same note, what makes the difference between them? The whole difference between the vowels consists of a difference in the number and proportion and comparative loudness of the over-tones. When we sing *a*, *e* on the same note, the difference is that when we make the *e* we do something which alters the over-tones that made *a;* and so, again, when we change the tone to *o* or to *ah*, or to any other.

If we carefully notice when we do this, we shall feel that something is happening inside our mouths. We are moving our throat in a different way; we change the position and the shape of the tongue, or, in some cases—as when we change the sound to *o*—we move the lips.

How we can make different sounds by moving the voice organs

In all these cases the larynx is unchanged, and the vocal cords are just doing what they did at first; but we are altering the shape of the spaces above the larynx—the resonators, as they are called—and so the over-tones are changed, and, instead of the particular set of over-tones which we have agreed to call *a*, there comes another which we have agreed to call *e*, and so on.

Children learn to make these sounds by imitation. That, by the way, is no explanation of how it is done, but still it is done. Now, youth is the time for learning, and afterwards not only is it difficult to learn new things, but also it is difficult to unlearn what we learned in youth. Different languages have different vowel sounds. Probably, on the whole, none of them is more difficult to learn to pronounce than any of the others. The question is really at what time in our lives we are asked to do so.

Every nation calls the sounds of the words of every other nation jaw-breaking for this reason. In English, for instance, we do not have the vowel sounds represented by the German ü or *ue;* nor has our *o* exactly the same sound as the Italian *o*. So we find it very difficult to make those sounds when we try to speak those languages, and, as a rule, we do not make them rightly. We may talk very good German or Italian, but the German or the Italian knows very well that these are not the languages we learned from the cradle.

Why a foreigner can never speak English correctly

In just the same way, a foreigner may use English far more correctly and wisely than we do ourselves, but though he lives half a century in America, and though he may be a very musical person, yet he will not make his vowel sounds quite correctly. The lesson of this is to teach us how marvelously delicate are the tiny movements of tongue and throat and cheeks and lips which decide the difference between *ham* as we say it, and *ham* as a German, speaking English, says it.

Another of the consequences of the fact that children learn by imitation is that if people, as children, have unfortunately heard the vowel sounds not quite rightly made, it is hard work, and perhaps impossible, for them ever afterwards to get them quite rightly. Now, to make the vowel sounds properly is a mark of having a delicate ear, and of having been surrounded by people who rather cared about these things, and so, though a man may speak beautifully and be a wicked man, or talk with a "shocking accent," as we say, and be a hero, it is worth while, perhaps, to pay more attention to this matter than many of us do. The number of possible vowel sounds is almost endless, for every possible position of the parts of the body concerned in speech will alter, by affecting the over-tones, the sound produced by the vocal cords, and so each of these positions will correspond to a different vowel sound. But, as we know very well, speech consists not only of vowel sounds, but also of consonants, like *b*, *c*, *d*, *f*, *g*, and so on, and of these, also, there are a very large number.

The difference between a vowel sound and a consonant sound

The first thing for us to learn is, what makes the difference between a vowel and a consonant, and there is no doubt at all as to the answer. The difference between a vowel and a consonant is the difference between a musical note and a noise—that is to say, the difference between a series of regular sound waves and an irregular disturbance of the air. All the vowels are musical notes; to be more accurate, they are blends of many musical notes—the principal one and its over-tones. Now, *i* and *o* are just as much musical notes as *a* or *ah;* but if, instead of saying *ah*, we say *ark*, we are using a consonant, and it takes very little time to prove that we are now making a sound which is not a musical note at all, but a noise. There are many proofs of this.

For instance, the ear tells us the difference in pleasantness between a language full of harsh consonants, such as German, and a "liquid" language, as we say, like Italian, where two consonants of different kinds are scarcely ever allowed to be next to each other, and where the most is made of the vowels. In general, the higher the proportion of vowels to consonants in a language, the more musical we call it.

Some sounds that nobody is able to sing

Again, we know that it is possible to sing a vowel, and though we may sustain the note for many seconds, we are all the time quite certainly producing the sound of that particular vowel—if we sing properly. But no one can sing a consonant, because every consonant is really an interruption, and nothing else, to the musical tone produced by the larynx. We seem to sing the letter *m*, it is true; but, in fact, when we listen to ourselves, we find that, after the first instant, we are simply singing through our nose a note which is neither *m* nor anything else. This fact of the nature of consonants, as compared with vowels, is very important, both for the singer and the speaker, but in quite different ways, and everyone who speaks or sings knows the difference.

Why a singer likes to sing in Italian

The first business of the singer is to sing—that is to say, to make music. But the singer is, as a rule, asked to sing words, though sometimes he may be allowed to sing for a little while a mere vowel like *ah;* and words are made up of vowels and consonants—that is, of sounds which are themselves musical, and sounds which are the very opposite of musical; some very unmusical, like *s*, and some less so, like *l*.

Thus, for choice, the singer will use a language, such as Italian, where the proportion of vowels to consonants is high, and when the consonants *do* come in, which, of course, they must if what he says is to be understood, he makes a point of dealing with them very quickly. Let them be definitely uttered, so that the people may hear what is being sung; but let this be done very quickly, because they are noises interrupting the music—every one of them. When we begin to learn to sing, we are all liable to try to sing on the consonants, and the first thing we have to learn is to do the singing on the vowels, which alone can really be sung. It is interesting to note, by the way, that the air-waves made in singing, and even in speaking, will throw scattered powder into patterns, and on an accompanying page are some pictures drawn by the human voice.

THE GREAT IMPORTANCE TO A SPEAKER OF PRONOUNCING HIS CONSONANTS WELL

To return to speaking, the first business of a speaker, as contrasted with a singer, is to be understood, and when we come to study the words of any language, we find that the differences between them are due more to consonants than to vowels. The rule for the speaker, therefore, is exactly the opposite of the rule for the singer. Whatever happens, he must make no mistake about his consonants. He must not drop his voice at the ends of sentences or at the ends of words. It may be just at the end of the word that the consonant comes which tells people what the word really is. The fortunate and rare speaker is he who manages to get his consonants clearly enough sounded so as to be understood, and yet is not compelled to sacrifice all the music of his vowels. Such a speaker is a delight to listen to, for he satisfies both needs of his audience—the need of pleasant sound and of understanding without effort.

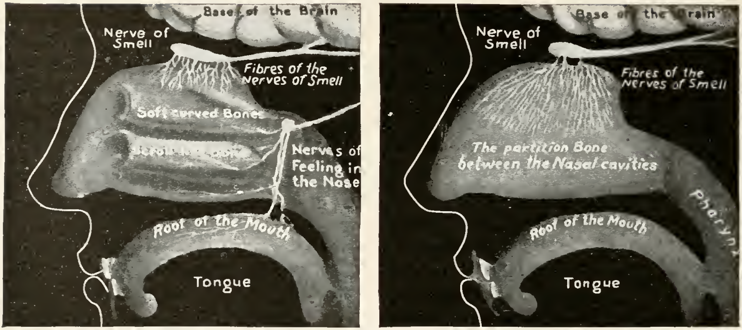
We do not need to study the consonants very long before we find, either by noticing what happens in ourselves or by looking at other people, that they can be classed. Certain parts of the organs of speech are specially used in making one set of consonants, and other parts in making other sets. For instance, we notice that we make *p*, *b*, and *m* with our lips, and so they are called the *labial* consonants, after the Latin word for lip. The first two we make by a little explosion of the lips, the difference between them being due not to the violence of the explosion, but to the quickness of it.

THE USE OF THE TONGUE AND THE TEETH IN PRONOUNCING OUR WORDS

Then we notice that the tongue is mainly used in the making of such vowels as *l* and *r*. There is certainly no doubt about the *r* if we roll it. Then there are certain consonants where there is no doubt that we use the teeth, as, for instance, *d* and *t*, and these are called dentals; and there are others, such as the sound *ng*, in which we evidently use the soft palate—that is, the back part of the roof of the mouth. So we call that a palatal consonant.

The larynx has nothing to do with the consonants, for, as we have seen, its business is to produce musical tones. We have also seen that the quality of sound produced decides the vowel, and that this is decided by the position of the tongue, the lips, and so on. It follows that if we allow air to pass up between the vocal cords, but without using them, we can still produce all the vowels and consonants; in other words, we can whisper, and that is what whispering is.

Thus, just as there are defects in speech due to defects in the machine, as, for instance, loss of the teeth, so also there are defects due to what controls the machine, and the chief of these is what we call stammering.

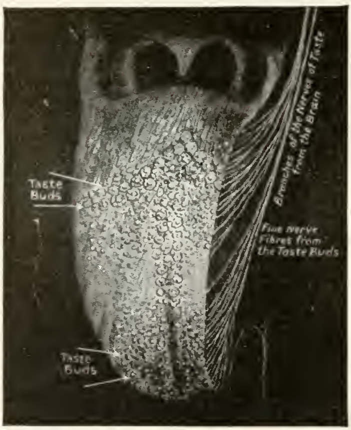


In the first of these pictures we see the outer side of the nose, with the nerves of smell and feeling, and the second picture shows the inner part of the nose, with the dividing plate of bone between the two nostrils.

SMELL AND TASTE

SMELL and taste are two senses which are of very trifling importance compared with hearing and vision, and we certainly need waste no time in troubling to ask how they may be taken care of; but they are, nevertheless, very interesting. These two senses are often called the chemical senses. Unlike hearing and vision, they do not depend upon waves, whether in the ether or in the air. We only smell or taste when the thing is actually touching the parts of the body which have this power; we see and hear at a distance, so to speak, but we cannot smell or taste at a distance. When we seem to smell at a distance, particles of the thing we are smelling have been carried through the air to the nose. This fact that smell and taste are so limited in their range makes them very inferior to hearing and vision.

Only a very small part of our knowledge of the world in which we live enters by these two gateways of knowledge—the senses of taste and smell. We know that these two senses are in great decline among the higher animals, and especially in mankind. While the senses of vision and hearing have become more important, the senses of taste and smell have become less so. These two senses are closely allied, and they very commonly work together. The taste of such a thing as cinnamon



In this picture of the tongue, the side has been removed to show how the nerves run from the sense organs, or buds of taste, to the brain. The taste buds are grouped at the back and tip of the tongue.

is very like its smell. A very large part of what we usually call taste is really smell. This is true not only of the aroma of coffee or tea, but also of the flavors of ordinary articles of diet. We can prove this for ourselves by noticing how differently our food seems to taste when the nose is thrown out of action by a bad cold.

We do not smell with the whole of our nose. Careful study with the microscope shows us exactly what part of the nose we do smell with. Roughly speaking, we may say that it is the roof of the nose and the upper third of it that we smell by.

The rest of the nose is lined by cells which have little projections that wave backwards and forwards and keep the channel clear; but the smell region of the nose is lined by special smell-cells, which correspond to the special cells that we found in the inner ear and in the retina. Each of the smell-cells is connected with a tiny nerve-fiber of its own. We find that this tiny nerve-fiber really grows out of the smell-cell, which is therefore a nerve-cell that has become changed. This is different from the rods and cones of the retina, or from the special cells in the inner ear, because they are not changed nerve-cells. The difference probably indicates to us how very ancient the sense of smell is, dating back to a time in the history of the body long before so many different cells had been made for so many different purposes as we find nowadays.

THE NERVES IN THE NOSE

The nose is supplied by two pairs of nerves coming from the brain. These two pairs of nerves are quite different in their duties. One pair has nothing to do with smell at all, but has to do with ordinary feelings in the nose. Anything tickling, or pricking, or hurting the nose affects these nerves; so does a thing like ammonia, which is irritating, besides having a smell. But this pair of nerves is not affected at all by scents that are not irritating.

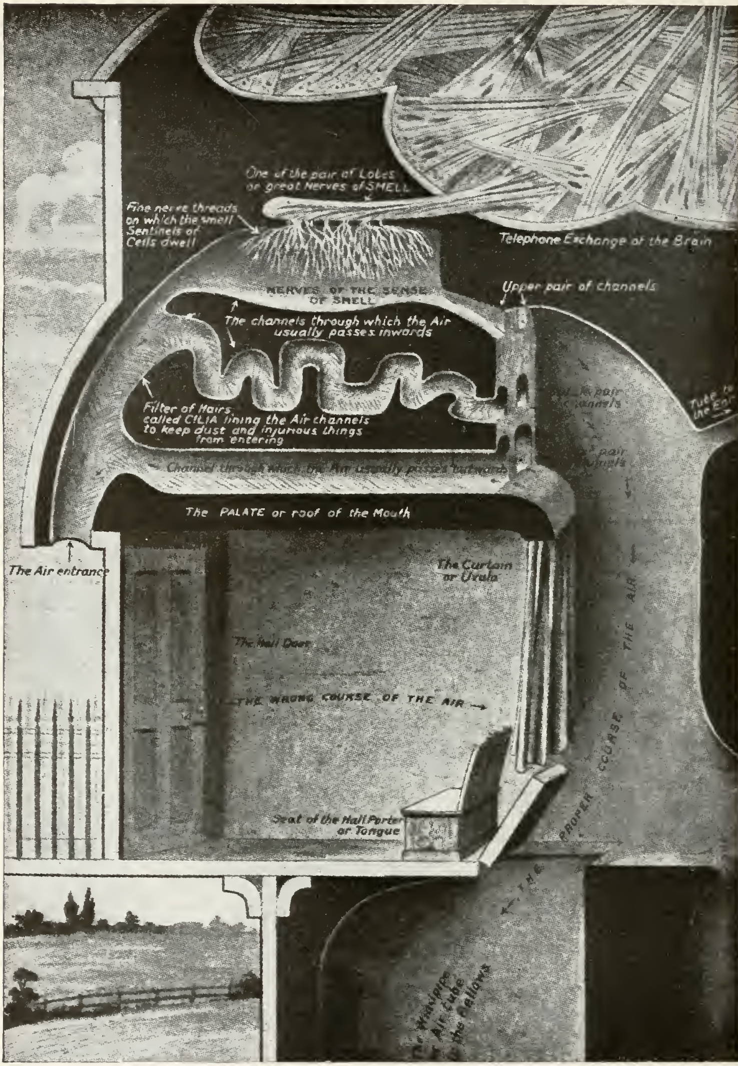
The other pair of nerves that come to the nose are the nerves of smell; they are known as the first pair of nerves, because they come off from the brain in front of any others. These nerves are apt to wear out, so to speak, in old age, so that old people lose, in some degree, their sense of smell, just as they often become deaf.

As everyone knows, there is an endless number of possible smells. Naturally, we wish to try to group them in the same manner that we group tastes, but it really is very difficult to classify smells in any way that people would agree upon. A very large number of oils found in plants have rather the same sort of smell, though, perhaps, it is not very easy to recognize any particular resemblance between such smells as turpentine and lavender.

FAMILY LIKENESS OF SMELLS

Still, on the whole, there is a general family likeness between the smells of plants and flowers; and, when we examine the oils that cause these smells, we find that they are related to each other in their chemical build. There are certain other groups of smells, such as the group to which carbolic acid belongs; and we can learn enough to see that there is a connection between the chemistry of a compound and its smell, but that is about all we can say. It is interesting to notice that electricity can stimulate our sense of smell as it can stimulate all our senses, and the sensation it causes is rather like the smell of phosphorus. It has also been shown that if we take a series of chemical substances which differ from one another in a regular way, their properties of smell also differ regularly.

WHY WE SHOULD BREATHE THROUGH THE NOSE



All sensible people breathe through the nose and not through the mouth, and this picture shows the reason why. The little hairs lining the channels of the nose act as a filter, keeping back dust and other harmful things, and the value of this filter is lost if we breathe through the mouth, where dust and germs have free entrance into the lungs. This picture shows also the little cells which enable us to smell, and the picture on page 138 shows more clearly the nerve of smell, seen at the top of this picture. When we smell a thing, small parts of it break away and touch the cells which live on the nerve of smell, and these cells can detect a particle of musk that weighs only a thirty-millionth of a grain, the sense of smell being more acute even than the eye aided by the microscope.

For instance, there is a long series of chemical substances beginning with marsh-gas. This has no smell—a very unfortunate fact for miners. The next member of the marsh-gas series has a faint smell, and farther on in the list the smells become very strong. It is also noticed that the things which have the most smell are the things, as a rule, which weigh heaviest.

Sir William Ramsay advanced a theory about smell, more than a quarter of a century ago, which is probably nearer the truth than anything else we can say. He thought that the power of exciting smell increases with the size of the molecules of a substance, provided, of course, that it is a liquid, or a gas, and not solid. Hydrogen, oxygen, and nitrogen have no smell, probably because their molecules are too small.

What smell depends upon and what taste does not depend upon

The first member of the series of alcohols has no smell; the next, which has a larger molecule, has a faint smell; and the still heavier alcohols have very decided smells. All this is very far from fully explaining to us what happens when we smell.

It is interesting to notice that sneezing cannot be excited through the nerves of smell, though it can be excited through the nerves of ordinary feeling in the nose, and through the nerves of sight. Lastly, it is noticed in the case of all the senses, more or less, that they are aroused by differences outside them, and soon take much less notice of what excited them very much at first, if it remains the same.

This is more striking, perhaps, in the case of smell than in that of any other sense. We have all noticed how quickly we cease to be aware of a smell which at first was perhaps very unpleasant.

Taste

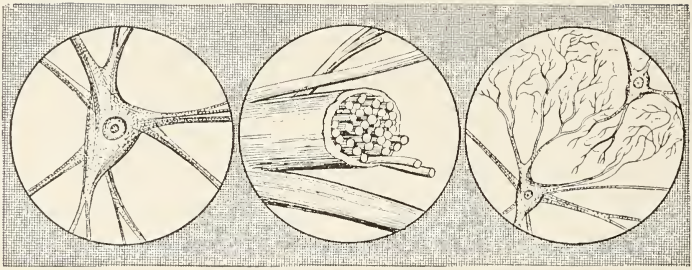
The sense of taste resides mainly in the tongue, but does not depend alone on the tongue. The special cells which are concerned with it, corresponding to the special cells found in the organs of the other senses, may also be discovered on the lower surface of the soft palate, and scattered over part of the throat in front of the tonsils on each side. A person who has lost his tongue does not entirely lose his sense of taste.

As in other cases, special nerve-fibers run to the cells of taste, which are most rich on the back part of the tongue, along the upper part of the edge of the tongue, and its tip. Taste is much less acute on the front part of the surface of the tongue. We can notice this especially if we place a quinine powder there and then swallow it.

Tastes can be classified much better than smells. Most of them come under the headings of bitter, sweet, acid, alkaline, and salt. The last three of these are probably not pure tastes, but mixtures of taste and ordinary feeling, so they can become painful when they are very strong. But bitter and sweet are probably pure tastes, and, however strong, and unpleasant, they can never cause such pain as the others do.

If things are to be tasted, they must be dissolved in a liquid.

With great labor and difficulty, the nerve-fibers that have to do with taste have been traced from the tongue, palate, and throat to the brain. The curious thing is that there are not separate nerves of taste as there are nerves of smell, vision, and hearing; but the special nerve-fibers of taste run along in other nerves which have nothing to do with taste, and they do so in a most extraordinarily complicated way.



In the left-hand picture, showing a nerve-cell magnified, we see the nucleus and nerve-fibers. These fibers may intertwine with those of another cell, as seen in the right-hand picture, but they never unite. The middle picture shows a bundle of nerve-fibers in their sheath, with smaller bundles branching off.

THE FOREST OF NERVES WITHIN US

IF we feel gently at the back of the elbow, rather towards the inner side, we find a thing that feels like a sort of cord, and if we squeeze it or knock it accidentally, we discover that it is what we call the "funny-bone." It is a nerve, and therefore belongs to the most marvelous of all marvelous things. If we take a nerve and look at it, we find that it is just a cord made up of tiny threads which are called fibers. It is these fibers that are the real nerves. The big cord is simply a bundle of them bound together into a larger cord.

A nerve-fiber is a thing which is probably not to be found anywhere in the vegetable world, but these things begin to appear quite low in the scale of the animal world, and their importance and number become greater and greater as we ascend. There is no part of the body that has not nerves supplied to it, and there is no part of the body that does not suffer in some way or another if the nerves running to it be damaged or cut.

When we examine a nerve-fiber, we find that it is a very long thread, usually surrounded by a sheath or coat which contains a quantity of a special kind of fat. There are a great many points of view from which we can think of a nerve as if it were an electrical wire, and the sheath may be regarded as what is called an insulator—a thing to prevent the current that flows in the nerve from leaking outside it. It is very interesting to take a modern electrical cable such as men lay in the Atlantic Ocean, and to cut it across and see what it looks like; and then to take a good-sized nerve and cut it across and magnify it so as to compare it with the cut cable. We see at once that men have found it useful to make their cables on exactly the same principle as nerves are made, with bundles of fibers big and little, all carefully insulated from each other. Of course, the nerve is much more wonderful, but the general principles of the way in which the nerve-fibers are packed together, and the way in which each is sheathed so as to prevent any leakage of its precious current, are really just the same as in the case of the cable.

When we excite our "funny-bone," as we call it, by hitting it, we feel a tingling in our fingers. We have excited the fibers which carry feeling along the nerve from the fingers to the brain. In other cases when we excite a nerve, muscles will twitch. We have excited fibers which carry orders along the nerve from the brain to those muscles. This shows that nerves carry something, and may do so in either direction, from the brain, or to the brain. The nerve-fiber is therefore a conductor. It is just like the wires in the cable. They do not make messages, but they carry them. What runs along the wire will run in either direction. Any particular nerve-fiber carries what it carries only in one direction; however, it has been proven that it *may* carry messages in either direction.

THE LIVING NERVE THAT CARRIES MESSAGES THROUGH OUR BODIES

The wire carries an electrical current. As long as the wire is not broken, and is properly insulated, the current will run. The wire is not alive, and, though we by no means understand what happens in it, yet it has not about it the mystery which we find when we look at a nerve.

For the noteworthy thing about a nerve is that it will only carry what it carries when it is alive. We can remove a piece of nerve from an animal that has been killed, and can study it in various ways. If we keep it moist with water containing a little salt, and if we keep it warm enough, it will live for quite a long time, and as long as it is alive things that disturb one end of it will send something through it. But when it dies it will no more carry messages than a piece of string will.

What makes the difference between life and death in the nerve we cannot understand until some day, perhaps, we shall learn what life is. We can see no change under the microscope to account for this difference, for we have to kill the nerve in order to look at it under the microscope.

THE MYSTERY OF THE NERVE CURRENT THAT NO MAN CAN UNDERSTAND

The thing that runs along the nerve we call a nerve-current, or a nervous current. Current simply means something that runs, and that is really almost all we know about it. It is not the same as anything else in the world; it directly depends upon the life of the nerve, as we have seen. It is not electricity. Curious changes are produced in a nerve when a nerve-current runs along it, and among these changes is the production of electrical currents of various kinds, which have been long and carefully studied. These show that an electrical change has been produced in the nerve when a nerve-current runs along it, and the study of these electrical changes may help us to understand the nerve, but it is a very great and serious mistake to suppose that the nerve-current is electrical.

Electrical currents in a cable or anywhere else move at a wholly different speed from that of a nerve-current. Nerve-currents have been measured again and again, and they travel at rates which, compared with the movement of electricity, are very slow. The rate of a nerve-current seems to be about the same as the rate at which a baseball can be thrown. An electrical current is hundreds of thousands of times faster.

Nothing seems to be used up in a nerve when it conveys a current, any more than in the case of a telegraph wire. So we cannot make a nerve tired. As long as it remains alive, it will go on sending currents as often as we choose to start them in it. The case of a nerve-cell is very different.

THE NERVE-CELLS UPON WHICH ALL OUR FEELINGS DEPEND

We have only been talking about conductors, remember. We have, so to speak, taken a piece of one of these conductors, just as if one took a piece out of a cable, and we have studied that. But if we wished really to understand telegraphy, we should have to study what is at the ends of the cable, and that applies to the case of the nerve, too. We found that we could excite a nerve by hitting it against something, as when we hit our funny-bone, or by pinching it; and there are dozens of other ways, as, for instance, by giving one end of it an electrical shock, dropping chemicals on it, and so on. But, of course, that is not what happens naturally in our bodies. We must find where the nerve comes from.

Every nerve-fiber grows out of a nerve-cell. It is part of that cell. It is only the servant of the cell, carrying orders from it or messages to it. The real thing, where the greatest mystery lies, and upon which everything depends, is the nerve-cell. When we study the development of the body, we find that every nerve grows out of the cell that it belongs to; we find also that, if a nerve be cut across the part which is next the cell is unhurt but the part which is separated from the cell invariably dies. We find also that, if a nerve cell is destroyed or poisoned, the nerve-fiber running out from it invariably dies, and if the nerve-cell has been actually killed, that nerve-fiber can never recover.

So these "cable wires" are not merely alive, but they are created by living cells, of which, indeed, they are living parts. That is one of the marvels which make a cable a very simple thing indeed compared with a nerve.

The dense forest of nerves that grows up in our body

A nerve-cell may have only one fiber coming from it, or it may have several. Very frequently, for certain purposes, we find nerve-cells which have one fiber coming out from each end of them. The fibers from any nerve-cell are very often found going to meet the fibers from another nerve-cell. Suppose, then, we can trace a nerve-fiber from a cell somewhere in the brain, for instance, and we find that it meets another fiber from another cell, perhaps at some other place in the brain. It is interesting to know whether the two fibers run into each other. Careful study shows that the fibers never run into each other. At their extreme ends they break up into tiny little fingers, so to speak, and the fingers of the two fibers will interlace; but they never run into each other. If we study parts of the brain where many nerve-cells and nerve-fibers exist together, we find, as someone has said, that it is very like a dense forest. Their leaves and branches intermingle with each other in the closest possible way; but they never actually join. We shall never find a leaf that belongs to two trees.

What the simple brain of a bee or wasp is like

All this is very important, because it teaches us that just as a gas is made of atoms, just as the body as a whole is made of cells, so the nervous system is made up of true units which are also cells, and though these cells are of a very peculiar kind and produce fibers which may run right away from the body of the cell for inches or even feet, yet each cell remains a true unit.

In the very lowest animals that have nerve-cells and nerves, the number is very few, and the arrangement very simple. They are usually arranged merely to carry feeling from the outside of the animal to its inside. But as we ascend the scale, nerve-cells and nerves get more numerous, and often, for convenience, numbers of them get bunched together into little balls, each of which is a sort of nervous center, perhaps somewhat like a telephone exchange.

When these collections of nerve-cells become very large, they make a thing that we can only call a brain, and such are the brains of a bee or a wasp, for instance. The whole arrangement of nerve-cells and nerve-fibers is called a nervous system.

When the first backbones came into existence, there also came into existence a number of new nerve-cells and nerve-fibers, and the central home of this new nervous system was inside the backbone. The old nervous system, such as the insects have, remained, and communications were established between it and the new nervous system.

HOW THE BRAIN SENDS AND RECEIVES MESSAGES THROUGH THE NERVES

In all animals that have backbones, both these nervous systems are found, and we may say very roughly that while the old one, which we ourselves inherit from the days before backbones, looks after the interior life of the body, it is the new nervous system that is the instrument of the mind. At its upper end, the long tube inside the backbone opens out, as we know, into the hollow skull; and in the same way the nervous matter which is found in the backbone, and which we call the spinal cord, becomes enlarged, and forms what we call the brain.

The brain and the spinal cord form what is often called the central nervous system. Through holes in the skull and through openings in the backbone run nerves which connect the central nervous system with every part of the body, and every part of the body with the central nervous system.

It seems quite clear that, whether we take the group of cells that forms a mere hair or any other of the least important parts of the body, we always find that it has a perfect double connection with the central nervous system. The brain, or the spinal cord, or both, can send to it messages upon which its life depends, and it, on the other hand, can send messages to them.

When we come to study the central nervous system, we find it so arranged by means of this double connection that every tiniest part of the body is really in true communication, when necessary, with every other part of the body without exception. It is this amazing fact that helps to explain how the body becomes a whole in spite of the infinite variety and number of its parts. In no city on earth, however rich in telephones, and speaking tubes, and telegraphs, and post-offices, and messenger boys, is there any arrangement a thousandth part as wonderful as the arrangement by which the nervous system connects all the parts of the city of Mansoul, as John Bunyan called it.

THE FOREST OF NERVES RUNNING TO AND FROM EVERY PART OF OUR BODY

We have already learned what is necessary regarding nerves. If we simply understand that the lining of the heart, the wall of a vein, the base of a nail, every muscle-fiber, and all other parts of the body are doubly connected by nerves with the central nervous system, we do not need to inquire how and where these nerves run; though, of course, the doctor has to spend long months and years in studying this. We must devote ourselves now to the central nervous system, and especially the brain.

The central nervous system consists, in a way, of a number of levels, or layers, and, as the bodies of animals have become more and more wonderful, new layers have been piled up on the older ones, and each new layer is the master of all the layers below it.

It is in this way that we can come to understand the working of the brain and the spinal cord. The spinal cord is very old; its business nowadays is to attend to things which are beneath the notice of the brain, as, for instance, the movements of the stomach and that kind of thing. It is a sort of highly trusted and responsible foreman in the house of man, and, like other foremen, it not only looks after a great many small matters on its own account, so as not to trouble the master, but it is also the master's means of communication. As a rule, the master gives orders to the foreman, and then he does the rest.

THE SPINAL CORD THAT ACTS AS FOREMAN TO THE BRAIN

On the other hand, tradespeople and so forth, when they have anything to say, do not go to the master, but interview the foreman, and he takes the message to the master; so also does the spinal cord. When we close our hands, the brain, which gave the order, did not speak directly to the muscles of the hand. No nerve-fibers run directly from the brain to those muscles, but nerve-fibers do run from the brain to the spinal cord, which is the foreman. They give orders to certain nerve-cells in the spinal cord, and from those nerve-cells there run fibers which go to the muscles of the hand.

If we cut across the spinal cord, and take a very thin slice of it and stain it with various dyes that will show up the way in which it is made, we find that its structure exactly corresponds with its duties. We find in it fibers and cells. Some of these fibers are running to the brain, some from the brain; a great many of them arise from cells in the spinal cord, and run to other parts of the spinal cord, and end there. If, for a moment, we think of the spinal cord as a huge exchange, or place of business, then these fibers are like the private wires that do not come from or go to the outer world, but connect one part of the place of business with another.

THE WONDERFUL BOX IN WHICH THE CENTRAL NERVOUS SYSTEM IS KEPT

The usefulness of the spinal cord very largely depends upon the proper working of these beautiful arrangements which keep every part of it informed as to what every other part of it is doing, and enable different parts of it to act in harmony when they so require—which is practically always.

The picture on another page shows us the central nervous system as it appears when taken out of the wonderful box—the skull and backbone—which exists to protect it. We see how, at its upper end, the spinal cord becomes slightly thicker so as to form what we might call a bulb. That, indeed, is one of the names for this part of the brain. It contains the group of nerve-cells which controls our breathing, and the destruction of which means instant death; also another group of nerve-cells which controls the heart; another group which controls the size of the blood-vessels; another for the acts of sucking and swallowing; another which controls perspiration; and there are probably more. All of these are contained in a little portion of nervous tissue that is just about the size of the end of one's thumb. Above the bulb, things become very complicated. If we had to begin with the study of the grown-up human brain, we should never find the key to it; but if we study the brain as it develops, and if we study the brain in animals, the thing becomes clear. We see quite plainly that what is the lower underneath part of the brain in us, all huddled and squeezed together and completely poked out of sight by something else that has grown over it, is the old brain, the first brain that ever was, so to speak. It contains countless numbers of nerve-cells, arranged in groups with different duties. It is mostly concerned with movements of the body, and in lower animals it is also the place where hearing and seeing and feeling are done. In ourselves we know that some of these senses have become so delicate and wonderful that they require new machinery, and the old centers which were good enough for lower animals are now, in us, only half-way houses towards the new brain.

Behind the old brain there is a large and important piece of nervous tissue which has a name that really means the little brain. It is called the *cerebellum*. This cerebellum, we have found, gets larger and larger in higher forms of life, but we cannot find that it has anything to do with feeling. We do not hear or see there, it starts no movements, and certainly the will and the powers of thinking do not live there. We find that it is a great instrument for making the body do what we want. The power of balancing the body lives there. A drunken man staggers because he has poisoned his cerebellum. Also the balanced use of the muscles for complicated and delicate actions, like painting or playing the violin, depends upon the control of the cerebellum. It may be thought that these duties are not very exalted, and we may wonder, therefore, why the cerebellum should get bigger as we ascend in the scale of life. But we have already learned that the one thing in the world that we can do is to move things, our bodies and things outside them. Through this power of movement, and only through it, our minds can live and act. So it is very important that our control of movement should be as fine as possible.

It can be proved that in the main line of ascent of life, more and more delicacy and accuracy of movement have always appeared. Part of the history of progress is the replacing of strength by skill. Babies and small children are very clumsy, and as they gradually become more skilful, this means mainly that the cerebellum is developing and getting the powers which it has in grown-up people. In proportion to size of the whole body, the clumsy, stupid animals are those that have a very small cerebellum. The best example of this is one of the most stupid of all the higher animals, the hippopotamus. We can understand that when we catch anything, following it with our eyes, and then getting our hands or our mouth to it, we must be using the cerebellum. The hippopotamus has practically no idea of catching at all. It takes a very long time to even see things that it likes, and if they get into a corner, it is so clumsy that it has not sense enough to use either its feet or its mouth to get them out again.

THE LITTLE BRAIN OF THE GREAT HIPPOPOTAMUS

All this depends upon the smallness of its brain, and especially of its cerebellum. It is reckoned that the brain of the hippopotamus weighs about the same as that of the horse, the weight of whose body is only one-fifth as great. It has been proved over and over again that, in the history of life, success has always gone more and more to brains, to skill as against strength, to mind as against muscle. The hippopotamus is a remarkable instance of an animal that has survived through long ages from the days when brains in general were much smaller than they are now, and the explanation is not to be found in its huge size and strength, but entirely in its mode of life. Its size and strength could never have saved it against better brains.

In the past there have been far bigger and stronger animals than even the hippopotamus, and they have all died out, but the hippopotamus is content to live upon grass and similar plants growing in rivers. It has its nostrils right on the very top of its face, so to speak, and so it can lie with its whole body in the water, and just leave its nostrils above to breathe by. In this way it saves itself by hiding, and still lives on, while the other stronger and wiser animals have completely disappeared from the earth.

As we pass upwards in the scale of life, we find that with the growth of the cerebellum, and the development of skill, there comes a time when even the mouth, that dogs and cats and lions and sea-lions are so quick in using, is not a good enough instrument for the clever brain.

THE USE OF THE ARMS WHICH GIVES MAN HIS GREAT POWER

Something even better is required, and so, in the main line of ascent, we find that the animals called lemurs, which are a very humble and ancient kind of monkey, use their hands a little for grasping as well as walking, though they prefer to use their mouths, as anyone can see who feeds them at the Zoo. But when we reach the highest apes, we see that they find and examine, and lift their food with their hands, and then carry it to their mouths. The arms, then, limbs which for countless millions of years have been used by all sorts of different animals for the same purposes as the hind legs, and for no other, now come to have special purposes of their own, and every finger becomes precious.

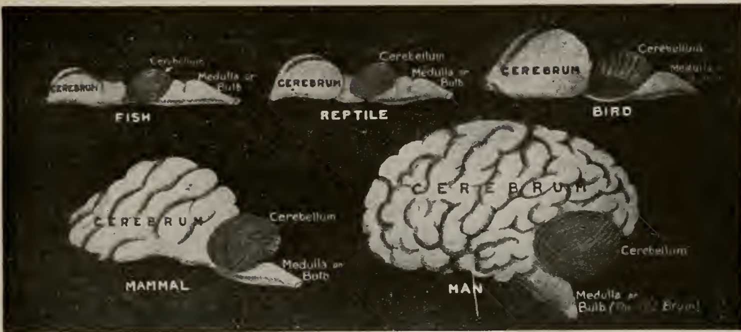
Cleverer even than the half-erect apes is man, who, after crawling babyhood is past, frees his fore limbs forever from the duty of locomotion, and learns how to use every one of his fingers separately, as with the typewriter or the piano. There has therefore been an immense development of skill in man—though mere strength has decidedly fallen off—and with it there has necessarily gone a great development of the cerebellum.

This is very interesting, because it helps us not only to understand the brain, but also to understand children. Children belong to a race that lives in the world by its ingenuity of all kinds, and so they like to practice their skill. This is why children love games of skill, and this especially is why, ever since children existed, they were fond of balls.

WHY IT IS RIGHT THAT BOYS AND GIRLS SHOULD PLAY

Of course, grown-up people do not like to have their windows broken; but still it is right and natural for children to play. What we call play, and stupidly think of as waste of time, is now known by wise people to be part of the necessary education of a child, if it is to reach the best possible for it in health of mind and body. Its play is really an essential part of the work of the child.

It is a pity that many children in America have nowhere to play but the street, no one to teach them good games, and no one to care what becomes of them, but the time will likely come when all children will be able to have happy playtimes.

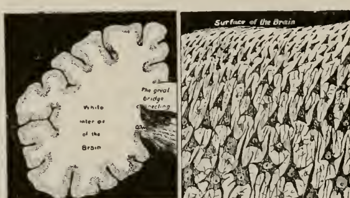


These diagrams enable us to compare a man's brain with the brains of other creatures. The size of each is drawn in proportion to the size of the creature's body, and we see that man's brain is very large.

MYSTERY OF THE BRAIN

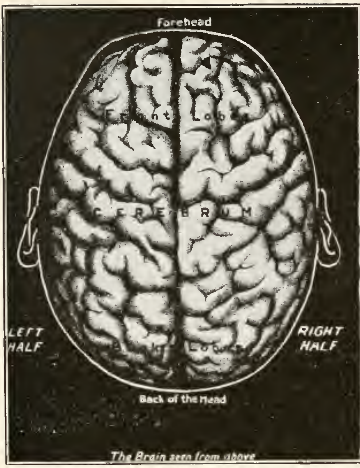
WE now know that, in ourselves, the highest and most important part of the nervous system is what may be called the new brain. One of our illustrations shows what it looks like when viewed from above, and the first thing we notice is that there is nothing else to be seen but the new brain. It is so large, and has grown out so far in all directions, that the whole of the older part of the nervous system is hidden underneath it. In an ordinary way, when we talk about a man's brain or brains, it is entirely of this new brain that we are thinking. The proper name for it is cerebrum. The word cerebellum, which we already know, really means little cerebrum.

Now, our first glance at the cerebrum shows us that it is a double organ. It has a right half and a left half. These two are just like each other, though it is probable that in right-handed people the left half, and in left-handed people the right half, is very slightly larger. We have, therefore, in a sense, two brains, just as we have two arms; for our bodies are built upon the principle of there being two halves corresponding to each other. If we slightly separate the two halves of the cerebrum, and look down between them, we see a mass of white nervous tissue which is evidently running across from one side to the other. This is a great bridge between the two halves of the brain, by which they are made to work and act as one. When we look at the surface of the brain, we see at once that it is very much folded; all over it the surface has been turned inwards into deep valleys. These vary in depth and length, but on the whole they form a very definite pattern,



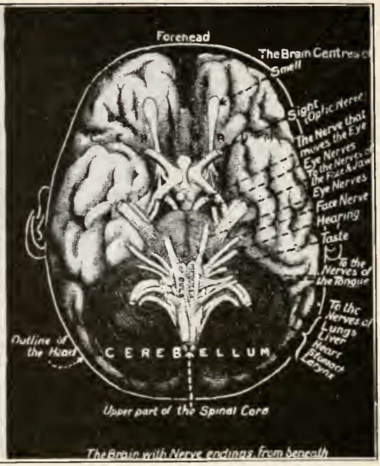
The left-hand picture shows a section across one side of the brain, and we see by the shaded border the thickness of the gray matter of the brain, as compared with the white nerve-fibers. On the right is a tiny speck of the gray matter, magnified a hundred times, showing the pyramid-like cells and the fibers.

THE INSIDE AND OUTSIDE OF OUR BRAINS



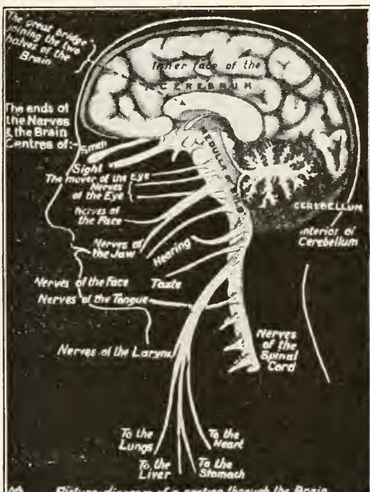
The Brain seen from above

In this picture we see what our brain would look like if the top of our skull could be lifted like a lid. The cerebrum, or new brain, is the part by which we reason out things, and it completely covers the cerebellum.



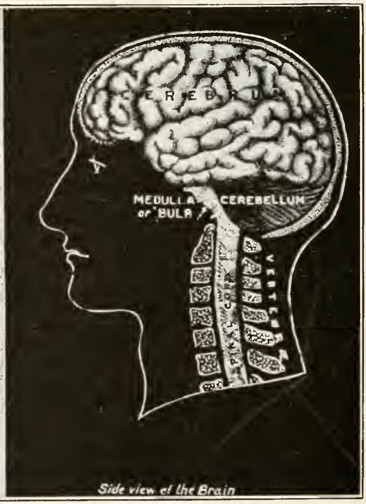
The Brain with Nerve endings, from beneath

Here we are looking up at the underneath part of the brain, and see the nerve-endings of the various senses and of the vital organs, all cut off short, except the nerve of smell, which is shown ending in a bulb.



Picture-diagram of a section through the Brain

This section of the brain, as seen from the side, should be compared carefully with the picture of the brain seen from underneath. In both pictures, the nerves are shown in the order in which they leave the bulb, or old brain.



Side view of the Brain

In this side-view of the brain, we see the proportion of the skull occupied by the brain. The convolutions, or folds, are shown, and the position of the brain in relation to the spinal cord and the backbone is easily seen which is the same on both sides of the brain, and the main lines of which are the same in all human beings. All the folds and the spaces between them have special names.

First let us understand what the folding means. The use of it is that it permits what is really the surface of the brain to be enormously increased, without requiring it to take up more room. Now the surface of the brain, as we shall see, is the all-important part. Brains have been growing bigger in the animal world generally for countless ages past. This means that there has been a great deal more room required to house the brain in, and so skulls have been getting larger. The size of the skull of man, compared with the size of his whole body, is simply gigantic. But though this is so, it very feebly indicates what the huge growth of man's brain has been, simply because the brain has grown far more quickly than the skull, as life has ascended, and has deeply tucked in its surface, here and there, as it went on growing, until there is now as much, or perhaps considerably more, of the surface of the brain tucked away than shows on the outside. In general, the higher the type of brain, the more is its surface folded. We can show this whether we trace the brain upward in different kinds of animals, or whether we compare different human brains with one another. As animals have become more and more clever, and have trusted more and more to brain and skill, rather than to size and strength, the surface of the brain has become more folded, and people who study the subject can tell in a moment, by looking at the surface of the brain alone, whether it belongs to one of the older kinds of animals or to one of the higher animals that have more lately appeared on the earth.

THE MANY FOLDS IN THE BRAINS OF VERY TALENTED MEN

A great many brains of famous men have been examined; many great men, indeed, have left orders that their brains should be examined for the advance of knowledge. As a general rule, these brains are found to be very highly folded. The contrast is very great between them and the brains of, say such an humble type of mankind as the Bushman of South Africa. Of course, this means that if we could unfold all the brains in question, and stretch out their surfaces quite flat, the wiser brains would be the brains with the biggest surfaces.

The size of the skull, its shape and the bumps on it, can tell us absolutely nothing whatever as to how much the brain is folded; still less as to what we shall find when we examine more closely what the foldings are made of. There is, on the whole, and in a very rough way, some correspondence between the size of the skull and the size of the brain inside it. But, for one thing, skulls vary in thickness; and, for another, no one can possibly tell what it is that is making up the size of the brain. Even if all skulls were the same thickness, and even if bumps corresponded to the brain, which they never do, the brain inside might be large because certain spaces inside it were swollen with fluid, or it might be large but have a comparatively smooth surface. It is quite easy to understand that a well-packed brain, which will go into a much smaller skull than another, may yet, if unfolded, have a far greater surface.

WHY THE SKULL CAN TELL US NOTHING ABOUT THE BRAIN

About a hundred years ago, when practically nothing was known about the brain, men thought that, by feeling and measuring the skull, they could learn about the brain, and so tell the character of the person to whom it belonged. Our modern knowledge of the brain has taught us that it is hopeless to expect this, simply because the things that really matter do not affect the skull at all. If a surgical operation were performed, so that a considerable portion of the brain were exposed and could be seen, then we might, perhaps, make a very rough guess as to what the person was like; but as we should have to judge how far we were right entirely by what we knew of the person in the ordinary way, it is difficult to see where the advantage of such an operation would come in.

Now, we must understand why it is that the surface of the brain matters so much. When we cut through the cerebrum of any of the higher animals, we find at once that it consists of an outside layer, which is gray in color, and an inside layer, which is white. This gray layer, which covers the entire brain, always dips down and up again wherever the brain is folded. There would be no meaning in the folds if it did not. It is often called the mantle, that is, something which is stretched all over the outside of the cerebrum.

THE REAL BRAIN OF MAN THAT IS THE MOST WONDERFUL THING WE KNOW

At no part whatever of either half of the brain, whether we look at the part it rests upon or in the depths of any of the folds, do we find this wonderful mantle lacking. It is the real brain, and, as we find it in mankind, it is the most wonderful thing of which we have any knowledge. It owes its gray color, and all its meaning and wonder, to the fact that it is mainly made up, not of nerve-fibers, but of nerve cells. The rest of the brain is made up of nerve-fibers or nerves, and these give it a white appearance, like that of an ordinary nerve in the arm or the leg; but the gray mantle contains only comparatively few nerve fibers, which connect its different parts in some degree.

HOW THE REAL BRAIN IS MADE UP OF THOUSANDS OF MILLIONS OF CELLS

What really makes up the gray mantle is thousands of millions of nerve-cells. These nerve-cells are vastly more wonderful even than those we find in the spinal cord, or those which are in the medulla and control our breathing, for they have to do with thinking, not to mention seeing and hearing, and so on.

Only a very few years ago, it used simply to be taught that when we take a very thin layer of this gray mantle, and look at it under the microscope, we see five layers of cells in it; one on the very surface of the brain, and so on, until the fifth lies next the white matter inside the brain. We can recognize these five layers because the cells in the different layers differ rather from one another in their size and shape and number. But now we can go much farther than that. It is, in general, true that we find about five layers of cells in any part of the gray mantle that we care to examine, but we also find that the cells differ very definitely in different parts of the brain. Also, if we carefully examine corresponding parts of the brain in large numbers of animals of quite different kinds, we find that the same arrangement of cells occurs in corresponding places.

THE LIKENESS BETWEEN THE BRAIN OF A MAN AND THE BRAIN OF AN ANIMAL

If a microscope slide containing a large number of cells shaped like pyramids and arranged in a certain way were shown a man who had studied the subject, he very likely could not be sure what animal the brain has belonged to, but he could say in a moment that that was the part of the brain which the animal used when it wished to move its muscles.

Again, if he saw certain curious little groups of cells lying not very far from the surface of the brain, he would say, without hesitation, "that comes from the part of the brain the animal smelled with." No one has the least idea yet what this particular group of nerve-cells has to do with smelling, but we always find them in the smell part of the brain, and nowhere else. This is equally true of creatures like the dog, in whom that part of the brain is large, and of creatures like ourselves, in whom it is comparatively small.

The parts of the brain which have to do with sight and with hearing are just as definite in their structure, so that it is vastly easier to tell that we are looking at something taken from the vision part of the brain than to tell what animal it was taken from.

The whole of the surface of the brain has been mapped out now very completely.

WHY A MAN'S BRAIN IS BETTER THAN AN ANIMAL'S

Now, when we have carefully learned to map out the various brain centers, as they are called, for the motion of muscles, for feeling from the skin, for sight, hearing, taste, and smell, we find that still the greater part of the whole surface of the brain is actually untouched. It is almost as if the greater part of the surface of the brain had no duties. We cannot find that it has anything to do with any of the duties that we can think of.

Now, when we begin to examine the brains of other animals, it soon becomes possible to take, shall we say, twenty different brains, and arrange them in an ascending order, beginning with the brain of some simpler kind of animal, as, for instance, a rabbit, and ending with the brain of man. If we do this we find a very wonderful thing. It is that the lower we go down, the nearer together in the brain are the different special centers which we have already found in the brain of man.

Indeed, when we go low enough, the whole brain practically consists of these various centers—for motion, and seeing, and so on—all lying right up next to each other. They make the brain. But to look at it the other way, as brains improve and get bigger, what happens is, not that these various centers get bigger, but that they become gradually separated from each other by the growth of new parts of the brain which appear and come to lie between the old centers. This process goes on and on, until at last in mankind, and only in mankind, it has reached the stage at which the various special centers, which long ago lay all together and were the brain, have become mere patches that lie here and there on the surface of man's huge brain.

What, then, is the meaning and the duty of these great new places that have come into existence, and to which the growth in the size of the brain is really due? When we question them, they are silent; indeed, they have been called the silent areas. We shall surely get some help in our studies if we can trace the course of the nerve-fibers that run out from the nerve-cells in these particular areas.

THE WONDERFUL FIBERS THAT LINK ALL OUR SENSES TOGETHER

As regards the special centers, we find that the fibers from the cells in them run just where we should expect. The fibers from the seeing centers run straight to the eye, the fibers from the hearing center are connected with the ear, the fibers from the center for movement run down into the spinal cord and are connected with the nerves that go to the muscles. These facts, of course, help to give us the key to the duties of these centers. If now we can find where the nerves run to from the silent areas, we shall guess what these areas really do, and it must be something very important indeed, because, whatever it is, it seems to explain the real difference between clever animals and stupid ones, high ones and low ones.

We find, then, that these fibers from the silent areas run in every possible direction, but in very definite groups and ways, to the other centers of the brain. What they do is to associate one part of the brain with another. I think we can understand that if there were no such things, then, though an animal might see very well, nothing that it saw would connect itself in that animal's mind with anything that it had heard, or felt, or smelled. Now, when we come to study the way in which we act, the way in which we put two and two together; when we notice how one thing makes us think of another thing, we begin to understand how it is that the association fibers make all the difference in the world between a high brain and a low one.

Where a Man's Brain Differs from the Brain of a Dog

If we compare the spinal cord or the medulla of a dog with that of a man, there is nothing worth mentioning to choose between them. If we compare the new brain of a dog with that of a man, we find a difference, but it is one which mainly consists in association fibers and cells. If we compare the vision center of a dog with that of a man, we find the two in the same part of the brain in each case, and with the same special type of cells.

The difference, however, is that the gray mantle in the case of man is much thicker; and when we come to inquire into what makes it thicker, we find that it contains a vastly greater number of fibers, which are running to it from other parts of the brain, and of new cells, which have nothing to do with seeing itself, but which send fibers out from the seeing center to all the other parts of the brain. In general, then, we may say that the differences between a high brain and a low brain are, first, that in the various special centers the gray mantle is much thicker in the high brain, because it is crammed with new association cells; and second, that in the high brain the special centers are forced apart by the growth in between them of new parts of the brain, which do not mean the invention of any new kinds of senses, but mean bringing all the parts of the brain into closer relation and connection with one another.

Some of Our Senses That Are More Noble Than Others

There are one or two very interesting exceptions to this rule, and they have a meaning. It must have struck all of us, if we ever think of our senses, that some of them are more noble than others. We agree, do we not, that it is a more dignified thing to enjoy a picture than to enjoy a chocolate? Someone may say: "Well, in either case, we are simply using one of our senses; why is not one as good as another?" But when we suppose that vision and hearing are more noble than taste and smell, we are quite right, and the reason is that they are more human. They reach a higher development in us than in any other creature, while so far as concerns smell, about which a great deal has been learned, it is probable that our brains are far inferior to those of almost any other creature that has a brain at all.

The sense of smell, that is weak in man and strong in animals

If we study the smell part of the brain in different kinds of animals, we find that smell reached its perfection ages ago, when vision and hearing scarcely existed. But such a sense as vision is far finer than smell, because not only does it act at very great distances, but it gives us a thousand times more information than smell can possibly give.

Therefore, part of the history of progress in the world of life has been that sight has improved and has largely taken the place of smell. This is most marked in ourselves. The dog is a very high kind of animal, and belongs to an order which ranks next to the monkeys themselves, and we all know how splendid the dog's scent may be. But in our own brains the part which corresponds to smell has shrunk to almost nothing; it is, indeed, so small that it took a very long time to find where it was; while the vision part of the brain has become huge.

The great growth of the back of the cerebrum in man is due to the importance of vision to him, for it is the extreme back part of the cerebrum, on both sides, that we see with. Our real eyes are at the back of our heads. We have already learned that the cerebellum is very large in us; but even though this is so, the vision part of the cerebrum has grown so enormously that the cerebellum is completely hidden from our sight by the cerebrum, when we look down upon the brain from above.

The difference between one kind of sense and another

It might be supposed that there is something wrong here, because many animals, such as birds of prey, have far keener sight than man has. That, indeed, is so; but are we right in supposing that the mere keenness of a sense is the highest thing about it? Not at all. The point is the extent to which we can use the information that the sense gives us, and the way it is linked up with every other part of our minds. The vulture can see a speck on the desert sand at a tremendous distance, but will the vulture enjoy a fine picture, or feel itself made humble and pure before a sunset? Of course, when we ask questions like this, we see at once what it is that really makes a sense high. No known animal has in the vision center of its brain anything like the depth and variety of structure that we have in ours. This is the great fact for us to remember about the place where the seeing is really done.

We have seen that smell and taste are comparatively unimportant in man, and in both cases there was long argument, and much work had to be done, before we could be sure in what part of the brain these two senses really lived. It might be supposed that the sense of touch would not be greatly developed in man, and that perhaps it is rather falling into the background, like smell and taste. This is a very great error, however. The most intelligent of all birds is the parrot. We notice this not only in its power of imitating sounds, but in many other ways.

Why the sense of touch is called the mother of all the senses

Now, it is an interesting fact that the parrot has a far more delicate sense of touch than any other bird. It really has quite a good notion of using its claws as fingers. It has the idea of stroking and feeling what a thing is like as we say. Now it is not just a chance that the most intelligent bird is the bird with the best sense of touch. It is what we should expect. The sense of touch is the mother of all the senses, in a way, and good education of the sense of touch is the foundation of all good education.

Probably some of those who read this will disbelieve it, but all the great students of the mind know that it is perfectly true, and have been saying so for scores of years. We are learning to understand what games mean for children, because they train the sense of touch and teach it how to work with sight; and we are also beginning to learn that drawing and carpentry, and the sort of things that children do in kindergarten, are invaluable foundations of education. There was a time when it was thought that anything good for a child must be something that it disliked, and that anything it liked must be mere amusement. Who would think that the real meaning of the word school is leisure—doing what we feel inclined to do? Yet so it is.

Now there is nothing we notice more positively about an intelligent child, and any child is intelligent until foolish grown-up people begin to interfere, than that it loves using its fingers. Of course it gets into mischief, but the child that never got into mischief, and never touched things it ought not to have touched, was never yet taught to read. There are such children, but they can be taught nothing, and we call them imbecile.

Whatever happens, the healthy child must constantly use its sense of touch; it must forever be fingering things. Now we find that the touch part of man's brain is simply magnificent. It is the delicacy and the variety of his sense of touch and, far more than that, it is the marvelous way in which man's sense of touch is connected with all his other senses, that accounts for our skill, which is almost the most wonderful thing about us as compared with any other creature. Not in a thousand years could any other creature but man be taught, for instance, to read with the fingers, even if that creature had a brain that could understand.

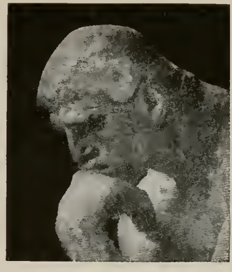
THE GREAT BRAIN PUZZLE THAT BAFFLED MEN FOR YEARS

For a long time it was a great puzzle to find the touch center in man's brain. It lay, so to speak, under our very eyes; but we never thought of looking for it there. A very large area of the gray mantle on each side of the brain is the center for voluntary movement, and it is here that the will of man gives its orders. For many years we knew this, and called it the motor center; and when we were looking for the center of the touch sense we never thought of looking there. But now we have found that the center for will and movement is the center for touch. The two lie mixed up together, and the connection between them is the closest of all connections in the nervous system.

THE WONDERFUL NERVES OF HEARING THAT ENABLE US TO ENJOY MUSIC

The sense of hearing lives low down on the side of the brain. As we all know, this sense of hearing has led to the possibility of music and all that that means. As in the case of seeing, of course there must be good machinery outside the brain if a sense is to develop, and the history of hearing, like the history of vision, is partly the history of the ear and the history of the eye. Here, however, we must merely learn that the hearing center of the brain is very large in mankind, and that when we examine the cells contained in it we find a state of things that exactly compares with what we found in the case of vision. It may be that some animals can hear sounds so slight that we cannot hear them.





"Thought," as Expressed by Three Famous Artists

The first of these pictures is from Michaelangelo's statue of Lorenzo de Medici, the second is from a painting by Sir John Millais, and the third is from a statue by a great French sculptor, Auguste Rodin.

HOW WE THINK

THE putting of things together in the mind, or association, as it is called, is the beginning of all the powers of which we are most proud; but though the usual name for it is the association of ideas, yet it does not apply only to ideas, but to everything that can enter the mind—a scent, a pain, a tone of voice, and thousands of other things that cannot be called ideas at all.

We know that there is a stage beyond seeing, and that is perceiving, and the proper name for a thing perceived is a percept. Like everything else, except mere sensation itself, perception depends upon memory. The case of a puzzle picture, where we look for a long time and at last perceive a face, is a good instance of the difference between seeing and perceiving, and the same applies to hearing sounds and recognizing them as a tune.

But these things that we perceive and make percepts are not ideas; they are simply a certain set of sensations put together and made into a whole. Perception is a great advance upon sensation, no doubt, but there is something better still, and the proper name for that is conception, or conceiving, as when we say, "I conceive that the stars must all be suns." That was the great idea, or conception, of Giordano Bruno, and it is evidently something beyond the mere perceiving, or recognizing, that certain colors and shadows we see make a chair.

We have passed from the mere level of things looked at, or sounds heard, to the region of thinking. Here is an idea, or a concept—a thought. Two memories have been put together in the mind and connected, or held together, by it in a certain way. Previously there were in the mind the memories of certain percepts; first, the stars, and secondly, the sun. But the mind performed the great act of conceiving; it associated, or put together, the two percepts, the stars and the sun, and it made a new and different thing—the thought that the stars are suns.

For thousands of years men had not only seen the stars and the sun, but had perceived them, and had carried in their minds clear memories of the stars and the sun, so that they could recognize them when they saw them again. But not until the mind of Bruno said "The stars are suns and the sun is a star" had anyone performed this great association of ideas, to use the old name. This instance we have chosen is a great one, but we perform little associations of ideas every day, whenever we think at all. A great instance has purposely been chosen, because what we are trying to understand is the building up of the mind, and such a case as this helps us to realize the orderly stages of the mind's wonderful ascent from the mere sensation of seeing up to one of the greatest ideas in the world. Let us just observe for ourselves how the stages follow upon one another.

How a child's mind is gradually built up

John Locke said that there is nothing in the mind except what was first in the senses, and that everything which comes to be in the mind is built up out of sensations and reflections upon them. Now, this is true, even in such a tremendous idea in astronomy as that the stars are suns. This begins with mere sensation. The mind begins its existence in babyhood and childhood without any inborn ideas of any kind. Its first experiences are mere sensations. The eye, as we know, is made from a part of the brain which has come forward outside the skull—"The brain comes out to see," as has been said. The eyes are turned upwards, and certain impressions of light are gained. These are mere sensations.

If there were no such thing as memory, they might be repeated every night during a lifetime, and nothing would come of it. But living matter remembers.

So, beginning with sensation and with the necessary help of memory, we pass to the stage of perception where the points of light seen one night are more than seen, for they are perceived to be the same as the points of light that have been seen on former nights.

Real thinking is putting things together in the mind

Percepts are remembered just as sensations are, and so we may go about with the percepts in our mind of the stars and the sun. Then one man singled out from the rest puts the two percepts together, and so makes a concept by this process of conception, or thought, and says the stars are suns. This teaches us the slow and necessary order in which the mind is built and grows, and the dependence of its highest deeds upon its humblest deeds. It is also a good instance of the truth that all thinking is association of ideas. The word conceive means "to take together;" the word associate means "to make companions;" and all thinking is putting things together—making companions of them, making a relation between them.

To some extent we all do this without effort or intention, but beyond a certain point we are very apt not to trouble about it. The point where we stop the process is the point at which our interest ends. Thinking is not a thing that happens to us, but a thing that we do, and in all doing a motive power has to come from somewhere. The motive power in this great doing of the mind, which we call thinking, is interest. Here we come to the key of one of the great differences between men, and, if the study of the association of ideas taught us nothing else, it would still be well worth while to study for this.

The secret of success in all great thinkers

We are right to admire the "kings of thought," but we are very wrong in our notions of what makes them great. It is true that in certain departments there are very special powers which one brain has and another has not; this is true of mathematics, for instance, and of music. But, apart from that, there is nothing more certain than that most of the great thoughts, and most of the great discoveries of mankind, might have been thought or made by anyone if they had been interested enough.

The secret of most of the great deeds done by the minds of men, in the way of pure thought or association of ideas, has been the great difference, not in the way in which the great minds associate, but in the fact of interest and patience leading them to go on thinking, endlessly revolving the ideas in their minds, and at last finding out the truth.

For, of course, associations of ideas may be false or true, or they may be merely fanciful, not pretending to be true, as when we say the moon is made of green cheese. But the greatest business of the human mind in its power of association is the discovery of truth, and we ought to have a right notion in our heads of what we mean by truth.

We may think of our mind as a kind of mirror in which the outside world is reflected. Outside then there are things and the reflection of things in our minds ought to correspond to the things as they are. Things outside and thoughts inside ought duly to reflect each other. Very often they do not. Our image of the outside world is distorted and twisted, or there are huge gaps. But, to some extent, our thoughts, the associations of our ideas, do genuinely correspond to the associations of things in the outside world; and then we can say that our thoughts are true.

THE THINGS THAT MAKE A MAN A GREAT THINKER

Anyone can associate any ideas; there is no difficulty about that. We may say the stars are night-lights, and a fancy like that may have some good in it as a fancy; but the great object of our minds is to make our thoughts genuinely correspond to things.

The great thinker is he who not only associates ideas, but makes the associations correspond to the associations in nature. The virtue and value of the thought that the stars are suns is that that relation between the two in our minds is the relation between them in nature. The reflection of things in the mirror of our minds is so far perfect.

If association is an act of the mind requiring power to do it, if it is vastly important as it is because right thinking goes a long way towards right doing, and if interest is the great motive which makes the mind think, then, certainly, it is our business to find out how far we can help and foster this interest in our minds, and also to find out whether one kind of interest differs greatly from another in its value for this purpose.

HOW WE MAY HELP OURSELVES TO BECOME REAL THINKERS

In the first place it is certainly possible for us to foster interest in our own minds and in the minds of other people, and there are few more useful tasks than that of the people who go about trying to open other people's eyes, as we say, so that they shall see the interest of things and thereby start thinking about them.

There are false or doubtful kinds of interest, as well as good ones. A man may be interested simply in making money, and the machinery of association in his mind will work, in consequence, with astonishing skill and rapidity; or a boy may be interested only in passing an examination, and so his machinery of association works hard for a time at something or other, and after the examination he seldom or never thinks of it again.

The blame is not his but that of the system that makes a victim of him. Worst of all, perhaps, in its results, is the kind of interest which sets men studying things only in order to defeat someone else, or to prove that they are right, or to make a success for the party or the class or the church to which they belong against some other party or class or church. This kind of interest is extremely powerful and very general and, according to the universal laws of the mind, it produces its due result. Unfortunately interest of this kind and interest in money are the driving power of most of the work of association or thinking that is done in the world.

The harm of letting our thinking be guided by wrong interests

If association done under interests of this kind resulted in the discovery of truth, that would be good; but, as a rule, it does not. Interest in the success of our party or our class or our religion, or of the people who have paid us to think and argue, destroys the true working of association of thinking in two distinct ways—both are disastrous. One of them is obvious, and the other is not.

The obvious one is that it is to our interest now to make the worse appear the better reason. We do not now make all the possible associations in our minds until we find the one which seems the truest, but we simply make the associations which best suit our case, and then we try to persuade other people that they are true. Things are so complicated that most men, if they think a little—and their interest sees to it that they do—can make the worse appear the better reason, and so associations are formed which are false. This may benefit the person or the class or the country or the party, but in the long run it must injure mankind. We must believe that truth is far more worth while than falsehood, or else we had better stop thinking at all. But there is the second less obvious way in which the false kinds of interest lead men astray. In the last case men deliberately deceive other people, but in this case they unconsciously deceive themselves. This is because the whole process of association can be upset and changed by feeling. Long ago this was quite forgotten by men of science.

The way in which our feeling affects our thinking

There was a time when men thought that the intelligence, or intellect—the part which knows and thinks—was practically the whole of the mind. They took no notice of feeling, and they thought that our deeds proceeded only from the results of what we thought. It is very strange how men could have thought this, for everyone knows how largely our feelings determine our deeds.

But today we do not make the mistake of supposing that the intellect is the whole of the mind, and so we are prepared to understand how much the intellect is affected by other parts of the mind. Thinking, or association, is a kind of doing, and we have just said that doing is largely determined by feeling. When we feel angry we are apt to kick, or hit, and so on.

Now, what is true of other more obvious kinds of doing is also true of that very wonderful, though less obvious, kind of doing which is called thinking. What we feel often decides what we think. We want to win, for money or for glory or for spite; we are fighting another country and we want to prove that we are right; or we are fighting for our class or our church against people who dress rather differently, or who arrange the service rather differently in their places of worship. We fancy that we are seeking the truth, but we are not seeking the truth; and just for that reason we do not find it.

THE WRONGFULNESS OF BELIEVING ONLY WHAT WE WANT TO BELIEVE

This upsetting of the judgment by feeling so that as happens every day all over the world, men come to believe what they want to believe, is one of the most important facts in the life of mankind, and accounts for half the facts of human history. If we are at all sensible and watchful, we can soon notice for ourselves what happens, because it is apt to happen to every one of us; and we need not wait long for a chance of observing it. What we shall find is probably this: that somehow or other all the facts and ideas and memories which suit what we want to believe, or to prove or persuade other people stand out strongly in the foreground of our minds. We know that the secret of attention is interest, and these things which we want to believe interest us most, and so we attend to them most.

Unfortunately, we attend to them so much that we do not attend to the other facts and ideas which do not suit our case. But we cannot form associations unless we attend, and so the associations which we do form, and the arguments which we use, are all based upon the things we have attended to, the things that interested us most, the things that suited our case.

THE REASONS WHY MEN DO NOT ALWAYS SEARCH FOR TRUTH

We may be arguing with someone else who is interested to prove the opposite. Just as the points which favor us press up into our minds, so the points which favor his case press up into his. But really we do not listen to his arguments, and he does not listen to ours, and neither of us convinces the other.

This is the sort of thing that happens in politics, and most of the things men quarrel about. There is a certain amount of deliberate deception, but the great key to the differences of opinion which divide even intelligent men is self-deception, depending upon the way in which our processes of association are spoiled by our feelings and our interests.

This danger comes into everything, even into the discovery of truth. There are many reasons why it enters there also. It is not the discovery of truth, but trying to persuade people that we have discovered truth, that often leads to money or glory. Quite apart from that, when a man has said a thing, he likes to prove himself right and that, of course, is not quite the same as liking to find the truth.

Then there are motives like jealousy, or motives like trying to prove that something which is believed by our church or our class or the particular school to which we belong is right. All this only causes disaster. It means that a man, instead of looking at all the facts, looks only at some of them; it means that he sees the importance of facts that suit his case, and cannot see the importance of those which do not, and so he goes wrong.

But everywhere in all ages there are a few men who are real lovers of truth. They would rather give up their beliefs than believe what is untrue; they would rather believe the truth and be despised and hated than persuade men of something that is not true and be honored.

WHY A THINKER SHOULD BE INTERESTED ONLY IN SEEKING THE TRUTH

The success which in some measure always attends these people, so that, if their brains are of a high order, they become the great thinkers of the world, like Newton or Darwin, depends absolutely upon the quality of the interest which drives them. We must have interest in order to make us think, or associate, but we must have the right kind of interest if we are to think rightly.

We can see, if we study the work of such a man as Darwin, exactly the way in which this interest in truth, and in truth only, keeps a thinker right. He is afraid of only one thing, and that is of going wrong. If his object were to prove anything in particular he would be more interested in one set of facts than in another, but as it is he is equally interested in all facts, because all facts lead equally to the truth. They do not all lead equally to his theory, perhaps, but that does not really matter—it is so much the worse for his theory, and so much the better for the truth.

THE MAN WHO TRIES TO FIND FACTS, AND THE MAN WHO TRIES TO PROVE A CASE

Darwin began with a theory which came into his head, and then he spent twenty years working at it. People say that he spent twenty years trying to prove it, but that is simply not the case. If we study Darwin's mind, and the lines of the work he did, we shall agree that it is nearer the truth to say that he spent twenty years trying to disprove his theory. Indeed, he was trying to prove or disprove nothing, but simply to find the truth.

The success of the successful lawyer is, of course, entirely different. His business is to win his case. He therefore lays all the emphasis on the facts which favor it, and purposely keeps in the background the facts which do not. He gets the verdict of the jury but that is not the method to follow if we wish to gain the verdict of no jury, not even of all mankind, but the verdict of Truth herself.

A WISE MAN WHO KNOWS LITTLE, AND A FOOLISH MAN WHO KNOWS MUCH

It is of no use to store things in the mind if we cannot recall the right things when they are wanted. But people who have not studied the mind constantly make this mistake. A man may be a walking encyclopedia, and yet be very foolish. His mind is crammed with facts, but he cannot associate them rightly; they do not suggest each other to him in their true relations, and so they are simply useless. Another man may have only one-thousandth part of the knowledge, but a thousand times more wisdom, because the facts in his mind are properly sorted and arranged and connected and classified and compared, or, in a word, the facts are associated.

HOW TO REMEMBER

We know the great difference between seeing and perceiving, and we must now consider the memory, without which there could be no real perceiving. It is just because memory makes perceiving and even higher things possible that its importance is so tremendous. If we could not remember, we should be nothing. Without memory there would be no recognizing, there would be no learning, no knowing. We are so accustomed to use this power of memory that, we think, we cannot realize what we should be without it. We see something coming along a road, far away, and then, after a while, we perceive that it is a human being. Later, by the dress, we can tell that it is a man and not a woman, but who it is we cannot tell. Finally, we find that it is someone we know. Here we see that the memory acts even in the simplest kinds of perceiving, and that it is worth while to devote some time to the study of it.

NOWADAYS, in dealing with such a great question as that of memory, we do not make the absurd mistake of trying to understand our memories without studying every kind of memory wherever we can find it; and the first great discovery we make is that, in some degree or other, memory is a property of every kind of living creature. Formerly it was said that memory was a property of every kind of nerve and nerve-cell, and that is perfectly true, but it is not the whole truth.

During late years men have studied the behavior of humble forms of plants, and of animals so simple and lowly that no nerves or nerve-cells are as yet developed in them. Yet even here, almost at the beginnings of life, long before there is the least shadowy hint of even the simplest kind of brain, we find some proofs of memory.

All living matter is called protoplasm, and it is a fact that memory is a property of all living protoplasm everywhere. No matter how simple creatures are, we find that their behavior can be made to change by changing their surroundings. This means that in some degree they remember; they act differently because something has occurred perhaps three times before, and the fourth time it occurs they do not behave exactly as they did the first time. What it is in living matter, whether of a nerve-cell or of any other kind of cell, that enables it to remember, we cannot say; neither can we say in advanced cases of memory, as when we remember an idea. But even in the humblest cases of memory, as where an animal behaves differently towards light because it is the second time and not the first time it has seen it, we can only guess what happens. The light the first time somehow made some kind of mark, as we might say, in the living cells, and altered them, so that the next time the light came they were different.

It is supposed by many people that living matter never forgets. When we say we forget, what we mean is simply that we cannot recall. But the thing we say we forget is still there in our mind, and when someone names it we recognize it; if we had really forgotten we should not recognize it.

But even where we cannot recall a thing for ourselves, and where we cannot recognize it when it is recalled for us by somebody else, it by no means follows that we have really forgotten. There are many cases on record where a man appears to have utterly forgotten, for instance, certain words of some language which he learned and spoke when he was a child; he cannot recall them, and they mean nothing to him when they are recalled; but he proves that they are still there in his mind when, perhaps, he is suffering from a very severe illness. His brain is greatly upset, and these words, which he may not have heard or used for fifty years, or more, come from his lips. Very likely they are used without any sense, and he does not know what they mean, but there they are. The brain has not really forgotten them.

THE DIFFERENCE BETWEEN REMEMBERING AND RECALLING

Such cases as these teach us that in all probability living matter does not forget, but, more than that, they show us that what we call memory is very far from being a simple, single thing. In what we call an ordinary act of memory there are three things involved. There is the pure remembering, with which we have not much more to do than a table has to do with remembering a dent made in it; there is the recognizing of what we remember; and there is the power of recalling. Everyone who has been asked at an examination, "What is this?" and who knows perfectly well that he has seen it a hundred times before, but cannot put a name to it, knows that memory is not such a simple thing as we sometimes suppose.

But in every act of memory the beginning of it is the making of an impression on the brain. No doubt this is a vastly different thing from making a dent on a table, but we do no harm if we think of it as if it were something like that; and, indeed, the only word which we can use to describe it, such as the word impression, which just means "pressing in," suggests a comparison of this kind. Now, as this is the beginning of all memory, it is very important for us to know how far and in what way we can improve this power of ours.

WHEN THE POWER OF THE MEMORY IS AT ITS BEST

We shall make nothing but mistakes unless we learn first to distinguish this part of memory from the other parts; and, secondly, to discover any natural changes in this power during the time that we grow from childhood to age. It is very likely that, on the whole, memory is at its greatest when we are young, and tends to diminish steadily as we grow old. There is an apparent exception to this, because at certain ages boys and girls seem to be able to learn poetry and many other things by heart with greater ease than they could have done a year or two before. But this is because the brain is, as it were, just being finished in its making. It is likely, on the whole, that after that the power of being impressed steadily diminishes.

This explains to us some facts about memory which seem peculiar. For instance, we know that, in a general way, we are more likely to remember things that have recently happened than things that happened long ago. This is probably only because the things that happened long ago are lower down in the mind, so to speak, and have been overlaid by many newer things.

WHY OLD PEOPLE REMEMBER BEST THE THINGS OF LONG AGO

Now we often find that old people instead of remembering the latest things best, remember them very badly; but, though they are doubtful about recent events, they remember quite clearly something that happened perhaps many years before. The explanation is that the newer impression was made on a brain that was losing its power of being impressed, but the older one was made on a young and very impressionable brain; and the passage of time has not destroyed the deep impressions made in youth.

When we compare different people, we find that there are differences between them in this quality of memory. It is supposed by nearly everybody that education accounts for these differences, and makes them. So one of the great objects of education is to "train the memory." But, if by training the memory we mean making the brain more impressionable than it is by nature, nothing can be more certain than that this was never yet done by any kind of education, and never will be.

To begin with, these differences between people are natural. The amount that a man remembers will, of course, depend upon the amount that he has tried to remember, and so his education is immensely important, because it largely means giving us opportunities for remembering. But that is an absolutely different thing from any effect in actually improving the power to remember, so far as this first part of memory is concerned.

The only excuse for learning a thing by heart

The differences between people in this respect are enormous, but they are natural differences, and we simply have to accept them as they are. Of course, they make a tremendous difference in our lives, because we have seen that memory is the basis of everything else; and though different kinds of memory are needed for different people—as for instance the painter, the engineer, and the musician—yet these differences in memory are the beginnings, at any rate, of the differences in what the people achieve.

It is quite certain, then, that the brain's natural power of being impressed cannot be increased by any of the methods which have been too long adopted for that purpose. There may be a good reason for learning by heart, simply because there are things which it is well to have in the mind, and which can be made to stick by repetition. But no kind of learning by heart increases the brain's power of retaining things. Learning by heart does not train the memory; it very often disgusts the mind and disheartens it from thinking.

The only possible defence for learning anything by heart is that the thing is worth knowing. There are plenty of such things, and the time will come when we shall carefully take children at just those ages when learning by heart is easiest, and deliberately use those years to put into their minds the best possible selection we can make of the things which everyone ought to know.

The things that we must know and the things that we should know

There are things that people must know and there are things that they should know if possible. The number of these things is a million times greater than could be remembered by the wisest and most learned man that ever lived. We must therefore do our best for each child, and that best will mean the careful selection of the things it should learn and the using of the time when remembering is easiest. We must break up and vary the lessons so as to avoid fatigue, because when fatigue begins, memory ends. Though education cannot improve the natural memory, yet there are certain things which education, in the widest sense of the word, can do or fail to do. Whatever the brain is meant to be by nature, and whatever is in its power to become, yet the building and the health of its cells and nerves, and therefore the success of their duties, depend upon the supply of blood they receive, and upon their never being subjected to over-use.

What we call education, which is sometimes just the opposite of real education, very often means that we injure the brain and spoil the memory at the very time when we think we are training it. School hours are often too long. Light, and especially air, may be defective. Foul air means foul blood, everywhere and always; and foul blood means that the brain also is being poisoned.

A HEALTHY OUTDOOR LIFE IS THE BEST AID TO MEMORY

Our great business, therefore, in taking care of our memories when we are young, is to lead healthy lives as much in the open air as possible; and no doubt we shall find that, in after years, for every one thing we remember that happened indoors when we were children, we shall remember two things that happened out-of-doors.

Next we have to consider the various special methods of impressing the memory. The first of these is the method of repetition. We all know that repetition helps us to remember, and, indeed, this method of going over a thing again and again is the one which has been most believed in since teaching began. This applies equally to our learning-memory and our doing-memory, as we recognize when we say that practice makes perfect. Now, so long as we clearly understand that repetition and learning by heart do no good to the memory itself, but merely help to impress it, we are quite right to use this method, and there are certain things well worth noticing.

THE BEST WAY OF REMEMBERING WHAT WE HAVE HEARD

One of the great methods of learning is to listen to something spoken and take notes of it. Now in such cases we notice that the two processes of listening and writing down and reading over result in much better remembering if they are close together. If we read our notes the same day as we take them down, we shall remember more a month hence than if we go over them a few days later. When the repetition comes close on the first impression, it is as if the iron were made hot by the first impression, and the second impression is more effective than if we wait for the first to cool.

Another most important fact is that one kind of repetition is very different from another, and this is one of the mistakes that almost all of us make. We may hear without "taking a thing in;" we may read or write a thing, or we may repeat it out loud, while our attention is somewhere else. In such cases all our labor is wasted, as certainly wasted for remembering the thing as it is wasted for "training the memory." It is no use trying to learn when we are tired or when we are feeling cold, thirsty or hungry.

WHY READING HELPS US TO REMEMBER BETTER THAN WRITING

It is worth noting that intelligent, careful, attentive reading of anything is a more effective kind of repetition than copying it out, though we should not suppose so. In copying out, as a rule, too much of our attention is devoted to the mechanical part of what we are doing, and so we are not really attending so well, though we seem to be working harder.

The secret of mere remembering lies, on the whole, more in attention than in anything else. It is most difficult to find out exactly what attention is, and exactly what happens when we attend. The difference between attending and not attending is probably that, when we are not attending, the disturbances that reach the brain from the outside world are scattered in all sorts of directions throughout the brain. The effects of them are almost wasted, because they scarcely go anywhere in particular; and it may be also that perhaps the most important parts of the brain, when we are not attending, are really not in action at all, so that the results of what is going on never reach them.

MEMORY TESTS ON THE BOOK OF OUR OWN LIFE

THE STORY OF THE EYE

What evidence have we that plants have eyes?

What insect possesses most powerful eyes?

Why does the house fly avoid a flame?

How are bees able to distinguish one flower from another?

In what respect is the vision of ants superior to ours?

In what respect does the eye of a backboned animal differ from that of an invertebrate?

What is the main purpose of the eyelids?

THE PARTS OF THE EYE

How does the cornea of the eye resemble and how differ from a curved piece of glass?

What purpose does the iris serve?

What determines the color of the iris?

In what respect is the lens of the eye superior to an artificial lens?

Why does a near-sighted person hold the book close to him?

What is the effect of age upon near-sightedness?

How is a cataract removed?

SEEING COLORS

What is light?

What relation exists between the numbers of ether vibrations required to produce the sensation of red and the number required to produce violet.

In what three ways do colors vary?

How many colors are there?

Name the three primary colors.

What is the cure for color-blindness?

What forms does color-blindness assume?

Why are red and green lights used for railroad signals?

THE MARVEL OF HEARING

How many senses have we?

What purposes are served by the outer ear?

Why can a dog judge better of the direction of a sound than a man?

How do we judge of the direction of a sound?

By what means is the canal of the ear kept clean?

To what is deafness in old age generally due?

What control have we over the intensity of sounds?

BALANCING THE BODY

What do you understand by the sense of balance?

What four different things aid us in preserving our balance?

How does a fish so easily preserve its balance?

Explain the connection between fish-gills and the semi-circular canals, ears and larynxes of higher animals?

Are the lower animals "dumb?"

What three duties does the larynx perform?

TALKING AND SINGING

In speech are all the words given in the same key?

Give the derivation of "monotone."

Give the derivation of "cant."

What is the essential distinction between speech and song?

What is meant by a "musical voice?"

Give the connection between over-tones and vowel-sounds.

SMELL AND TASTE

Explain the intimate relation existing between taste and smell.

What part of the nose do we smell with?

With what two pairs of nerves is the nose supplied?

Through which pair is sneezing excited?

What connection exists between smell and the weight of the substance scented?

Where is the sense of taste located?

Give the five principal classes of tastes.

THE FOREST OF NERVES WITHIN US

In what way does a bundle of nerves resemble an ocean cable?

Will a nerve fiber carry messages in both directions?

How does the movement of a nerve-current compare with that of an electric current?

Of what is a nerve-fiber a part?

What office does the spinal cord perform in the economy of the body?

What is the function of the cerebellum?

MYSTERY OF THE BRAIN

What connects the two halves of the cerebrum?

Why is the surface of the brain folded in convolutions?

Is phrenology based upon sound principles?

Whence do we derive the power of association?

In what sense are our eyes at the back of our head?

HOW TO REMEMBER

When we say we have forgotten a thing, do we mean that there is no record of it in the brain?

Distinguish between memory and recollection.

What is the beginning of a memory?

Why is it easier to remember recent events than those which occurred long ago?

The converse holds with aged persons. Why?

HOW WE THINK

What mental process follows perception?

Give Bruno's great conception.

What is the motive power of thought?

What effect has perverted interest upon our thoughts?

Explain how the judgment may be led astray by feeling.

What is the distinction between a "walking encyclopedia" and a great thinker?

STATUE OF LIBERTY ENLIGHTENING THE WORLD

Sculptured by Bartholdi and erected at the entrance of New York Harbor as emblematic of the civilizing influences of liberty upon modern civilization.

Book for Parent and Teacher

THE MONTESSORI SYSTEM OF CHILD TRAINING

Underlying Ideas of the System
Purpose and Educational Value of the Montessori Devices
Necessity of the Montessori Spirit
How a Montessori School Is Conducted
Montessori Exercises and Games
Use of the Apparatus
Discipline and Obedience
Memory Tests on Montessori System

THE SCHOOL OF REAL LIFE

What a Boy Must Do to Succeed
What a Girl Must Do to Succeed

PRACTICAL ARITHMETIC AND PROBLEMS

The Fundamental Processes

Addition — Subtraction — Multiplication — Division — Fractions — Decimals — Denominate Numbers — Percentage — Interest — Taxes — Insurance

Problems and Calculations in Connection with:

Education and Industry — Fencing — Drainage — Plowing — Wheat — Corn — Potatoes — Birds and Insects — Hay — Orchards and Spraying — Poultry — The Dairy — Roads — Silos — Problems with the Lever — Animal Power

Handy Values, Weights and Measures

FARM SCIENCE AND PRACTICE

Choosing a Farm
Rotation of Crops
Preserving Foods
Plant Life
Fifty Farm Birds
Stock Feeding
Fertilizers
Concrete Construction

DR. MARIA MONTESSORI

The famous Italian physician and educator who founded the Montessori system of child education

MONTESSORI SYSTEM OF CHILD TRAINING

FOR HOME OR SCHOOL

This Book explains how to train and develop the special senses; how to keep children properly occupied; how to train their bodies; how to use all necessary apparatus; and how to enforce discipline and obedience.

THE Montessori method is a new system of education for very small children devised by an Italian woman physician. One of the first facts rediscovered by Dr. Montessori is the old threadbare truism that every child is different from every other child. She found not only that but also that not being a fixed and inanimate object, he is in a constant state of flux, and differs from himself, from day to day, as he grows. His attention, his memory, his mental endurance, his intellectual interest and curiosity, are not only unlike those of the child next him in school, but will be tomorrow different from what they are today. It was evident to her that the usual "class recitation" and "class lessons" were out of the question, since they could at the best, possibly fit the needs of only one child in the class. And yet it is obviously impossible, as the world is made up, to have a teacher for every child. There was only one way out—things must somehow be so organized and arranged that, for most of the time, the child can and shall teach himself.

UNDERLYING IDEA OF THE SYSTEM

And here Dr. Montessori found herself in accord with another fundamental principle of the growth of childhood, which she had discovered or rediscovered and which may be said broadly to be the master idea of her system. The central idea of the Montessori system, on which every bit of apparatus, every detail of technic rests solidly, is a full recognition of the fact that no human being is educated by anyone else. He must do it himself or it is never done. The learner must do his own learning, and this granted, it follows naturally that the less he is interfered with by arbitrary restraint and vexatious, unnecessary rules, the more quickly, easily and spontaneously he will learn. Everyone who wishes to adopt her system, or to train children according to her method, must learn constantly to repeat to himself and to act upon, at every moment, this maxim, "All growth must come from a voluntary action of the child himself."

THE SYSTEM MUST FIT THE CHILD

In this respect again Dr. Montessori took the stand that education must be made to fit the child, and the child not forced to fit a preconceived idea of what education ought to be or do. She laid down the principle that one of the essentials of education is that children shall get that individual attention they need so much, by giving it to themselves, each child being his own teacher. She now further stated as another essential element that education should be so organized that the child shall ardently desire to teach himself and shall enjoy doing it more than anything else.

Basic principles of Montessori system

To reduce, then, to the barest outline this new system of training children, one can say that it rests upon a full conviction of these three facts about the nature of children:

First.—Children are all different from each other, and hence need for their fullest development, the greatest possible liberty for their individualities to grow; and that, though of course there are many points in common, they must not be treated in the lump, but individually.

Second.—Children cannot, so to speak, learn from the outside. That is, that the impulse to learn must come from within their own minds. There are absolutely no exceptions to this rule. Children must wish to learn, or it is a physical impossibility for them to do so.

Third.—Children are so made that, given proper conditions, they prefer educating themselves to any other occupation.

A day with the children's activities

What has been said thus far is almost certain to have aroused in the minds of many readers the question, "How in the world does Dr. Montessori accomplish all this?" or, perhaps the more skeptical exclamation, "It can't be done, by Dr. Montessori or anyone else!" How can children teach themselves? How can they learn without detailed verbal instructions from a teacher?

How does a boy learn to climb an apple tree? By being turned loose in company with the tree at that period of his life when he feels a surging natural impulse to climb trees. A boy of three can play about the foot of an apple tree day after day and no more think of climbing it than we of walking the ridge pole of our house. A man of twenty-one can play tennis, or plough, under the tree's branches with a similar lack of monkey-like desire to climb from branch to branch. But somewhere between those ages, there is a period in every normal life when, if the opportunity is present, a vast amount of muscular agility, strength and accuracy are acquired, together with considerable physical courage, some daring, some prudence, and a fair amount of good judgment, all without the slightest need either to force or persuade the child to the acquisition of these desirable qualities.

The purpose and educational value of the Montessori devices

Now, for all intents and purposes, the Montessori apparatus, so much talked of, so scientifically and ingeniously devised, is simply composed of supplementary apple trees. It is made up of devices and inventions which are intended, first, to stimulate the little child's natural desire to act and learn through action; second, to provide him with action which shall give him a better control of his own body and will-power; and third, which shall lead him naturally from a simple action to a more difficult one.

Trains the five senses

In the case of very little children this is (as far as concerns the formal

SELF-EDUCATION BY THE MONTESSORI SYSTEM

At undirected play with the didactic or sense-training materials

Montessori apparatus sold) largely connected with the training of the senses. The importance of this detailed, direct education of the five senses may not be at first apparent. But it is evident that our five senses are our only means of conveying information to our brains about the external world which surrounds us, and it is equally evident that to act wisely and surely in the world, the brain has need of the fullest and most accurate information possible. Hence the education of all the senses of a child to rapidity, agility and exactitude, is of great importance—not at all for the sake of the information acquired at the time by the child, but for the sake of the five, finely accurate instruments which this education puts under his control.

Montessori spirit is the first essential

Much has been written and said about the Montessori Didactic Apparatus, but the use of her apparatus without an understanding of the underlying principles and without the spirit that animates all true Montessori work will result only in confusion and disorder. The Montessori Didactic Apparatus is a part of the system, but the most vital element is the Montessori spirit. The mother on a desert island who is dominated by Dr. Montessori's love and respect for the child would accomplish much more without the formal apparatus than a mother who uses it without the sympathy and understanding requisite for success.

The casa dei bambini

If you wish to see a typical Casa dei Bambini (which means Children's Home) you are to imagine thirty children turned loose in a big room, furnished with little chairs and tables, with room outdoors, close at hand, where the children may run and play when they feel like it, a quiet, gentle, alert, nearly always silent superintendent, to whom all those little self-teachers turn for advice in their educational career; a piano in one corner of the room, to the music of which once in a while those children who feel like it dance and play. There are soft rugs on the floor, on which those children who feel tired may lie down and rest whenever they like. On the walls there are pleasant pictures of subjects suitable for little children. There are window-boxes of plants, tended by the little pupils; there are in one corner some little wash-stands with small bowls and pitchers where the children wash their own faces and hands, whenever they are dirtied by their work or play. In fact, the room and its furnishings are exactly like what every mother would like to give her own children in her own home. The Casa dei Bambini is truly a "Children's Home"—a place for self-reliant work and contented play.

Feel a responsibility

The children learn to feel, because they are allowed to, a real responsibility for the condition of this, their very own home. Before they begin the morning's work, they clean the schoolroom, using tiny brooms and dust-pans, just the right size for their little hands, and they make their own morning toilets neatly and cheerfully at the little washstands. They all seem like brothers and sisters of one big family, living the happiest and sanest of family lives together in one big, well-furnished nursery. They form groups of two or three, over some difficult problem; or four or five in a game with some part of the apparatus which needs a number of children together; or ten or twelve in a ring-around-the-rosy game to the music of the piano. Out in the playground, bright with flowers and plants of their own tending, there are always some children playing "blackman" or "blindman's buff." No one makes the slightest effort to induce them to stop playing in order to come and learn their letters or the simpler processes of arithmetic. They do so of their own accord. It has been found, first, that although they are free to do so if they wish, they no more wish to spend all their time in playing children's games than workers in a candy factory desire to consume chocolate drops all the time.

Value of free-will over enforced attention

The second discovery is of even greater importance than the first; is in fact of such vital importance that it cannot be too often stated. This is the discovery that one moment of *real* attention, given of the child's own free will, with actual vivifying interest back of it, is worth more educationally than hours of enforced listening to a teacher teach. Such a moment of real attention is worth more because it is worth everything, while the enforced listening to teaching is worth nothing.

Luncheon in the Casa dei Bambini—The children, as a rule, busy themselves happily with the different parts of the apparatus most of the morning. Towards noon, preparations for luncheon begin. The children take turns in doing this work, four or five being charged every day with the responsibility of setting the tables, bringing in the soup tureens, and serving their little mates. There is no better description of this most interesting and valuable part of the routine of the day than the passage in Dr. Montessori's own book, *The Montessori Method*, page 348: "Any one who has watched them setting the table must have passed from one surprise to another. Little four-year-old waiters take the knives and forks and spoons and distribute them to the different places; they carry trays holding as many as five water glasses, and finally they go from table to table, carrying tureens full of hot soup. Not a mistake is made, not a glass is broken, not a drop of soup is spilled. All during the meal, unobtrusive little waiters watch the table assiduously; not a child empties his soup-plate without being offered more; if he is ready for the next course, a waiter briskly carries off his soup-plate. Not a child is forced to ask for more soup, or to announce that he has finished.

Exercise their own choice

After lunch, the children again choose freely their own occupations. Some run out to play on the playground; some water the plants under their especial care; some take naps as long as they like. By far the greater number, however, return to the Montessori apparatus and occupy themselves with that fascinating material until time for them to go home.

MONTESSORI EXERCISES AND GAMES

TWENTY-NINE LESSONS WITH FULL DIRECTIONS TO MOTHER AND TEACHER

Including: How to fix the child's attention on size and form. How to co-ordinate movements of the fingers. How to distinguish differences in size and form. How to develop the sense of touch. How to train the sense of hearing. How to teach the child to write. How to teach the child the *abstract* from the *concrete*. How to teach the child the use of colors. How to train the child in bodily movements. How to teach the child the alphabet. How the child learns self-care. First steps in numbers. Arithmetical games. How to teach discipline and obedience. How to supplement Montessori apparatus.

WE IN America who have children between the ages of two and seven can not as yet send our children to one of the special schools. Therefore, if we wish our children to profit by the great work of Dr. Montessori, we must do the next best thing, and give them the Montessori training in our own homes. The fact that we have only the children of our own home to deal with should not lessen the sense of responsibility or the diligence with which we strive to make daily application of the Montessori principles.

A SCHOOL IN THE HOME

The mother has some advantages which the superintendent of the Montessori schoolroom does not have. She has the children constantly with her, and she can, if she will, turn into a Montessori exercise almost everything the child does in the course of his waking hours. These valuable and constantly present opportunities for supplementary Montessori work in ordinary home life will be touched upon as the regular apparatus is described and explained in the following lessons.

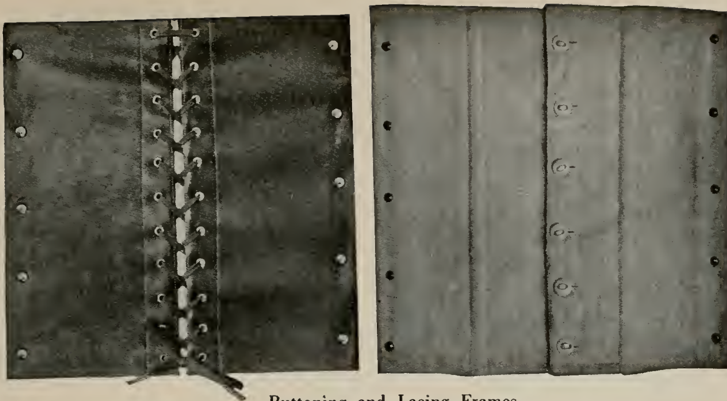
Let us suppose that the box containing the Montessori apparatus comes into the home when the three-year-old child for whom it is intended is asleep. The mother takes her time to look over the large collection of queer-looking objects and, if she is wise, puts away, for the present, everything but the simplest of the Buttoning Frames and the three sets of Solid Geometric Insets.

EXERCISE ONE

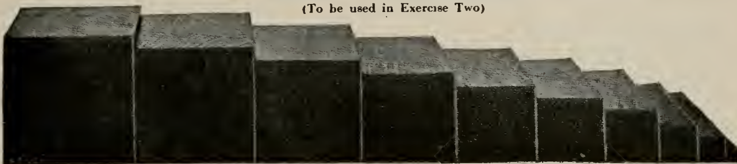
TO FIX THE CHILD'S ATTENTION ON SIZE AND FORM

Solid Geometrical Insets.—These comprise three series of wooden cylinders set in corresponding holes in a thick, smoothly planed board. There are ten cylinders to each of the three series. In the first, the height of the cylinders is constant and the diameter varies; in the second series, the diameter is constant and the height varies; in the third series, the cylindrical form alone is constant, height and diameter varying. With these insets, the child, working independently, learns to discriminate objects according to thickness, height and size, and the material used controls the error.

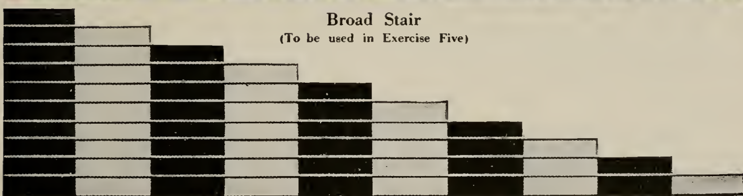
When the child wakes up, he is told there are some new playthings in the house, and one of the Solid Geometric Series is shown him. As a rule, he needs no further supervision in the use of this piece of apparatus, since it is self-corrective. If he gets a small cylinder in the big hole, when he comes to the small hole, the big cylinder will not go in it, and he is forced to look back to correct his own mistake. Here, as in the use of all the Montessori apparatus, it is well to remember that the best thing one can do for the child is to let him alone as much as



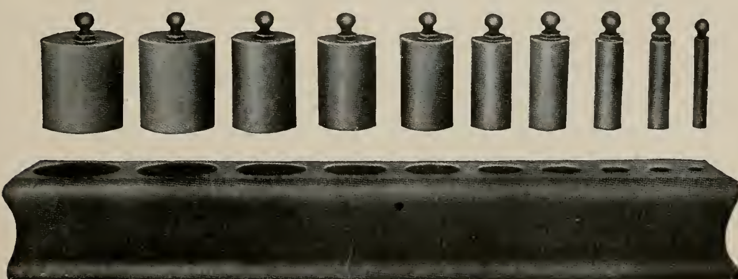
Buttoning and Lacing Frames
(To be used in Exercise Two)



Broad Stair
(To be used in Exercise Five)

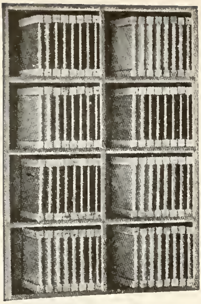


The Long Stair
(To be used in Exercise Six)



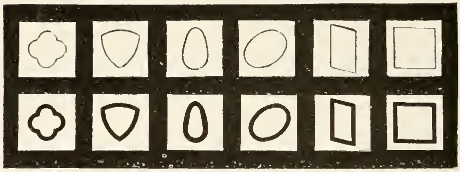
Solid Geometrical Insets
(To be used in Exercise One)

MONTESSORI SENSE-TRAINING APPARATUS

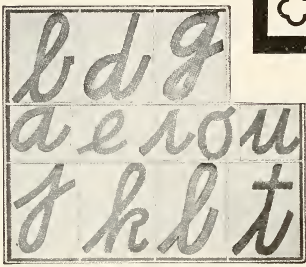


Color Boxes
(To be used in Exercises Sixteen and Seventeen)

Sandpaper Boards
(To be used in Exercises Seven and Eight)

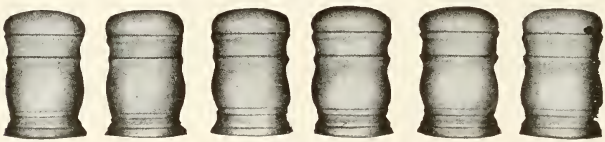


Plane Geometric Forms
(To be used in Exercise Thirteen)

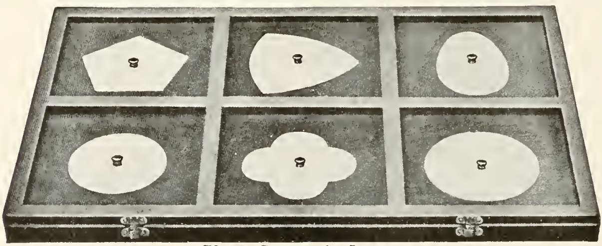


Part of Movable Alphabet
(To be used in Exercise Nineteen)

Computing Boxes
(To be used in Exercises Twenty-three and Twenty-four)



Sound Boxes
(To be used in Exercise Ten)



Plane Geometric Insets
(To be used in Exercises Eleven and Twelve)

MONTESSORI SELF-INSTRUCTING DEVICES

possible. "Hands off!" is the motto for adults in adopting the Montessori system for a child. The important thing is not that the cylinders shall all be put back in the right holes, but that the child shall do it himself!

Any ordinarily active, right-minded baby of three will fight for this right himself, pushing away help and crying "Let me," and the adults should religiously respect this desire to begin a life of self-independence. And yet, of course, adult brains can often devise some method of using the apparatus which will make the process of learning self-independence easier for the child. One of the discoveries made by Dr. Montessori is that the sense of touch is very much more developed in little children than the sense of sight; that is, they can tell more about an object after they have handled it than if they have merely looked at it. So that it is well to explain to a child who has difficulty in getting the cylinders back in the right hole that if he holds a cylinder by the little knob with the fingers of his left hand and passes the forefinger of his right hand around the base of it, and then around the opening into which he thinks it ought to fit, that he will probably be more accurate than if he merely looks at the two objects.

Traits of Child Nature Appealed To

It is well that the mother should understand just why the child should be interested in these exercises. There are two fundamental traits of childhood involved: first, any normal child takes a great interest in putting objects in rows; second, any child is delighted when he can put an object into an opening. Combining these two traits of childhood, we have a fascinating educational device. The child is not only happily employed but he is learning something that is of value. He is learning to discriminate between different objects. Although he does it unconsciously, he is forming an idea of spacial relations.

When the child can successfully put the various cylinders in their respective openings, the exercises can be made more complex by giving all the cylinders to the child and only one of the bases. This requires a greater discrimination, making the exercise more complex. The cylinders can also be used a little later in teaching nomenclature, to show the difference between thick and thin, thicker and thinner, high and low, higher and lower, etc.

After he has mastered the simpler exercises, the child may be blindfolded or, looking in another direction, place the various cylinders into the openings. These exercises bring into play the tactile and muscular senses, both of which are very acute in small children. Since the child delights to feel of objects, it will not be long until he will take a great interest in the game of "seeing with his fingers." These sets of cylinders are perhaps the simplest of all the equipment and at the same time they have proved the most fascinating for small children.

The Tracing of Forms, "The Beginnings" of Writing

The child should be cautioned (and his mother should take pains about this in all Montessori exercises) to make the motions always from the left to the right, in the directions in which writing is done, for these exercises, unlikely as it seems, are the beginnings of writing and reading. Then he should be left to "play" with this new toy, as long as his interest lasts, which will vary greatly according to the degree of development reached, the temperament of the child, and even his state of health. When he is perfectly well and rested and not hungry, he can do much better work than otherwise. His attention to the exercise must, of course, be spontaneous, brought about by the interest of the task given, and if the task does not happen to interest that particular child at that particular moment, nothing can be gained by forcing him or even coaxing him to go on with it. He will return to it another day, or perhaps even an hour later, of his own accord.

EXERCISE TWO

FOR CO-ORDINATING MOVEMENTS OF THE FINGERS

The Buttoning or Dressing Frames.—There are eight of the dressing or buttoning frames. Any one or more of these can be used effectively without association with the others. On six wooden frames are mounted six pieces of cloth of varying textures, to be joined by means of large buttons and buttonholes, automatic fasteners, small buttons and buttonholes, hooks and eyes, colored ribbons for bow-tying, and lacing through eyelets. The remaining two frames are mounted with leather pieces, one of which simulates shoe lacing and the other shoe buttoning, the latter involving the use of the button hook. These exercises are for the development of co-ordinate movements of the fingers. The child is taught to dress himself without his really knowing that a lesson is being taught him.

The Buttoning Frame, or the frame with "hooks and eyes," should be brought out first, and the method of fastening and unfastening explained in the usual Montessori way; that is, as briefly as possible. It is often best not to say anything, but merely to go through the exercises one's self, unbuttoning or unhooking the cloth, buttoning or hooking it up again, and handing the frame to the child. In most cases he at once sets to work, and even though his first efforts seem to the observing mother incredibly clumsy and slow, she must keep her hands off, and let him work out his own problems.

PUTTING AWAY THE APPARATUS

The only rule should be that if he does not wish to play witn the apparatus, or when he grows tired of its use, he should put it away; and for that purpose it is very essential that there should be a well defined place, which the child can easily reach, for every one of his belongings—not only for the Montessori apparatus, but for his other toys and for his clothing. The hooks should be low, so that little arms can reach them, and the drawers where clothing is put away should be easy to open and shut. Three years is none too young to begin the habit of order, which, like so many other good habits, may be acquired painlessly at an early age, although so nearly impossible to inculcate after the bad habits have become fixed.

The exercises with the dressing frames are not necessarily for the developing of the different senses. The primary object is to develop the muscular coordination to strengthen the child's little fingers. These materials carry out Dr. Montessori's ideas of simplicity, self-correction and general attractiveness. They are so simple that the child at once understands the meaning of the game, and in working with these various materials his little fingers and hands are so strengthened that he may successfully take up more complex and difficult work.

Of course, one of the incidents of this work is that he learns to dress and undress himself. This, it should be remembered, is not the primary factor that Dr. Montessori has in mind,

EXERCISE THREE

Supplementary exercises teaching the practical application of knowledge gained with the apparatus

One obvious result sought in all these exercises is the beginning in the child's mind of the habit of concentration to the task in hand. The insets are primarily intended, as already stated, to teach the child to distinguish between differences in dimension and form, and this can be taught by supplementary exercises in almost any room of the house.

First.—In the dining-room he can be given a pile of spoons of differing size, teaspoons, tablespoons, soup-spoons, coffeespoons, etc., and the suggestion made to him that it would be fun to separate them into piles according to their sizes. In most cases, this impromptu Montessori exercise can be depended upon to amuse the child for an astonishingly long period, and it is, of course, excellent training for his capacity to distinguish accurately between objects similar but of different size.

Second.—Out of doors, a pile of stones of differing sizes can be divided into several piles of the same size. Most mothers will be surprised at the vast and inextinguishable interest taken in such simple exercises by the average healthy child of three or over. The gain in accuracy of eye and brain is too obvious to need discussion.

Third.—The buttoning frames are intended first of all to teach the child to use his hands and fingers accurately and well, and next to enable him to dress himself as far as may be. This is very important, for the first thing to be done for a little child is to release him as quickly as possible from the prison of babyishness—to make it possible for him to take care of himself, and not to depend upon the services of others. As his clothes are nearly always fastened with buttons, it is essential that considerable time be devoted to teaching him how to manage these, or, rather, that he shall be allowed to take the time necessary to learn this. For he has a natural fund of desire to manage himself which makes him eager to learn.

The buttoning frames, being of cloth tightly stretched on wood, are easier for him to manage than the buttons on his own clothes, although as soon as he begins to try to button his own coats and waists, he should be allowed all the time he needs for his first clumsy and ineffectual attempts. Remember, he should be allowed all the time he needs—not all the help he needs! For if he is often helped, he will fall into the vicious, invalid's habit of waiting for other people to serve him.

Fourth.—The lace and ribbon frames are more difficult to use and are, of course, to be held back until the child is older, perhaps four or five. From time to time, they should be brought out and a simple experiment made of the child's capacity to deal with it. If he does not at once show interest in the problem of bow-knots and laces, and more of a capacity to struggle with the construction of them than on the last trial, the frame should be taken away, without comment, and not tried again until more progress has been made in the other exercises. It must be remembered, as a general rule for the use of the Montessori exercises, and in general in the training of little children, that no prolonged attempt should ever be made to coax them to continue an exercise which does not interest them. If they show no spontaneous interest, they are not ready for it, and time is only wasted by any attempt to force their inclination.

When they are ready, they can learn in ten minutes what three hours of dreary enforced practice was not able to teach them.

EXERCISE FOUR

Exercises four, five and six are also for the further cultivation of the child's visual perception of difference in dimension and form

The Block Tower.—After the child has had a day or so of practice with the Geometric Insets and Buttoning Frames, allowing him to take them up and lay them down at will, it is time to bring out the blocks composing the Tower. The Tower is a series of ten wooden cubes, decreasing in size. Almost every nursery possesses such blocks, but few mothers are aware of their educational value or of the distinctive use to which blocks of graduated size should be put. Their use should not be confused with that of the ordinary "building blocks,"—cube blocks of unvarying size. With the Tower blocks there are definite problems of classification and discrimination to be solved, and to get the benefit of them, the child must use them in the one correct way.

Teaching the Child to Build the Tower

The mother builds up the Tower before the child's eyes, placing the largest block first, then the next smaller one, and so on down to the tiny little cube at the top. Then she knocks it all down, and if her child is the average child, he needs no more incentive to duplicate the performance and to begin to educate himself as to graduations of size. When he begins to construct the Tower himself, the difficult thing for the mother to do is to avoid giving him elaborate instructions: "No, no, Jimmy—not that one—that's not the next size—don't you see the one by your hand is bigger?" etc., etc., etc. The only good Jimmy can get of this exercise is by learning to see for himself which is the bigger block, and to do this his mother must let him alone. She need not be surprised if he makes one odd mistake continually, even after he has learned quite deftly to construct the Tower. A great many children find it difficult to begin the Tower with the biggest block. They begin it with the next biggest, and, when they have finished, find that they cannot place the largest one without tearing down the whole structure. The psychological processes involved in this mistake are too complicated to explain here. I mention it, lest some anxious mother should think her own three-year-old especially deficient in the capacity to distinguish between sizes.

One exercise that can be profitably carried out is to give the Tower to the child and have him carry it, let us say, from one part of the room to another. In all probability, his first attempt will be far from successful. Let him take his own time in the building of it, and then make another attempt. Finally, he will be able to carry it very successfully from one part of the room to another, thus showing the self-control that is developed.

EXERCISE FIVE

Broad Stair

After the Tower, the next exercise is the Broad Stair. It is a set of ten rectangular wooden blocks, decreasing in height and width, length only being constant. This is another of the visual perception exercises. Here it may be well to mention that when a new exercise is given a child, the older ones are by no means taken away. They are left in the nursery, where he can get at them himself whenever he wishes to, and the new ones simply added to the store of his riches. Often, when the more elaborate exercises are quite mastered, a child will take pleasure in returning for a time to the simpler old friends with which he began. He should be allowed to do this quite as he wishes, his own instinct being a sure and accurate guide to what is best for him in this respect. He is doing what we all like to do occasionally—he is "reviewing" what he has learned, and making sure of his grasp on something which he has not thought of for some time.

The Broad Stair is brought out in the same quiet manner with which the child has been introduced to his other Montessori "playthings." The mother arranges the blocks in regular order, starting either with the biggest or the smallest, and laying the others side by side, until a regular stair is constructed. Then she mixes the blocks up, and goes away. The child, if he is ready for this exercise, at once takes it up, and in struggling to repeat his mother's feat, constructs the stair, intellectually as well as physically, and learns a new variety of dimension. Since all these blocks are the same length, and only differ in height and thickness, his problem is one degree more difficult than in the construction of the Tower.

It should be remembered about these blocks, as about all Montessori apparatus, that they should be used for the purpose for which they are intended and for no other. The child should always have, in addition, an ordinary set of plain building blocks, with which he can play in any way he pleases, and if he begins to "make houses," etc., with his Montessori blocks, his little mind, incapable of more than one idea at a time, should be redirected to the regular exercise involving the dimensions of these blocks.

EXERCISE SIX

The Long Stair

After the Tower and the Stair comes the third set of blocks, or rods, called the Long Stair. This is the most important of the three sets, as it is the foundation for instruction in arithmetic. With this set of short rectangular rods, the child learns, as he grows older, a number of the simpler processes of numeration. At first they are presented to the child just as a series of rods differing in length, the smallest one being one tenth of the length of the longest one. The mother builds up the series, having the child notice that all the rods are red on one end, and that the stairs have a regular number of red and blue spaces from one to ten, or from the bottom to the top of the stairs. Then the series is knocked over, the rods mixed up, and the child left to put it together again himself. Children who cannot definitely count can often manage this series, and it is the greatest pleasure for the child who has just learned to count to be able to verify his numbers in this concrete way. For the present, this is all that is done with the Long Stair, but as the child progresses and develops, it will be found one of the most valuable parts of the apparatus, because the rods can be combined in many different ways, and illustrate in the plainest and most unmistakable manner many of the simpler processes of mathematics — addition, subtraction, etc. But this all comes later, and after the child has mastered other of the apparatus.

Order of Exercises to be Modified According to Circumstances

It is not desirable that we give directions for the exact use and the order of succession of the remainder of the apparatus. Children differ so widely that the mother will be forced

CHILDREN DIRECTING THEIR OWN LESSONS

A spontaneous writing lesson. These children have reached the point where, as Montessori says, they "explode into writing."

Montessori Long Stair Game

to depend somewhat on her own judgment and intimate knowledge of the child. She will have grasped by this time the purpose of the exercises with the Montessori apparatus, which is *to give the child the fullest possible control over his own body and will-power.* The order of exercises as hereafter indicated is to be followed with any ordinary child, but this must be modified according to circumstances.

EXERCISE SEVEN

Developing the sense of touch

Sandpaper Board Number One.—As a rule, the next piece of apparatus to be taken up is the Sandpaper Board, a small board, one-half of which is smooth and the other half covered with sandpaper. This fixes the child's attention on the difference between surfaces. Sometimes this is one of the very first apparatus to be used, as a distinction between rough and smooth is apt to be one which arouses the interest of a very little child. His mother takes the board in her lap, or lays it on the child's small table, and draws the little finger-tips over the smoothly planed board, saying at the same time, "smooth, smooth." Then she draws the finger-tips (always from left to right) over the rough sand-paper, saying, "rough, rough." The child very soon associates the sound with the sensation, to which his finger-tips are more alive than are deadened adult fingers, and says himself, as he touches the two surfaces, "smooth, smooth—rough, rough." After this distinction has been thoroughly learned (it may take only one lesson, or it may take two or three days), it is a good plan to try to see if he can make the distinction accurately when he is not looking at the board, purely by the sense of touch. The finger-tips should then be passed, always with the utmost delicacy and with the lightest possible touch, over the two surfaces, and the child asked to give the right name to what he is touching. At the first sign of mental fatigue or confusion, this exercise should be discontinued, although it may be taken up again after a half-hour's rest and change of occupation. The child's fingers should always be trained from left to right.

EXERCISE EIGHT

Sandpaper board number two

When the simpler of the sandpaper boards has been mastered, the child may go to the next form, in which the sandpaper is arranged in alternate strips on the smoothly planed board. This is, of course, more complicated, and the blindfolded child may soon "lose his head" and not be able to distinguish accurately between the sensations. He should be encouraged to take plenty of time, and to allow his finger-tips to play freely across the surface. When he can tell quickly accurately, and without mental fatigue, whether he is touching a rough or smooth strip, the beginning of the child's education of his tactile sense is well made. He has taken the first step, which counts so much, and will go on steadily to more complicated conquests. In this exercise, the child is also learning to follow a raised surface with his little fingers. This is of great value to him as a preliminary to the sandpaper letters. After he has mastered this simple exercise, he has one of the first requisites necessary for successful work with the sandpaper letters.

EXERCISE NINE

For the further development of the child's tactile sense

In the formal Montessori apparatus, the small cabinet containing seven drawers is filled with various fabrics. These fabrics consist of two pieces of the following materials: velvet, silk, wool, fine and coarse linen, and fine and coarse cotton. It is very important that absolutely pure fabrics should be used for these first exercises; in short, the mother should be quite sure that the linen she is using is not partly cotton. Of course, if the regular Montessori apparatus is used, all of these precautions are provided for. These can be supplemented by any ragbag, and from the infinitely diversified fabrics used in the furnishing of any home. When this "playing" with fabrics is first begun, the child is allowed to handle the different pieces of cloth, and his attention is called to the difference in their texture. He is told their names, one or two at a time, the mother taking the greatest pains to pronounce the words clearly, distinctly, and SLOWLY. When he has learned to distinguish them by looking at them, the next step, as with the sandpaper boards, is to distinguish them by the sense of touch only. The child can be blindfolded, or can look up at the ceiling, and, sitting in front of a mixed-up pile of the pieces, takes them up one at a time, pronouncing their names. When he has done this enough times so that he is quite sure of himself (usually after a week of playing with the pieces at intervals) he can go on to some of the fascinating "games" to be played with them.

SUPPLEMENTARY EXERCISES AND GAMES INVOLVING THE SENSE OF TOUCH

First.—The pieces are divided into two piles, each having the same number of pieces of the same fabrics. Then the mother picks out a piece of velvet, without naming it, asks the child if he can find a piece like it in his pile (of course, without looking). This is always productive of much excited fumbling in the pieces, and much delicate fingering of them by sensitive little finger-tips, and finally much triumph when the matching bit of velvet is discovered. It may be said in passing that it is usually well to begin with either velvet or silk, as those fabrics are so markedly different from others that the problem is easier for a beginner. If two children play this "game," the victor is the one who first finds the piece of velvet without looking at his pile.

Second.—The mother's ingenuity can devise many other variations on this game, and can see to it that the child goes on observing the fabrics used in different parts of the house, the materials of which his own dresses are made, the stuff used in upholstery, table linen, curtains, etc. He can also be told the names of the different materials used in building a house—wood, iron, tin, glass, stone, and brick; and the materials of cooking utensils—china, tin, copper, etc. There is an infinite variety of material in the humblest home which can be the most valuable educational apparatus for the well-trained child, even in quite early childhood. Once the child's interest in this problem is aroused, he will in most cases go on educating himself, and all the parent needs to do is to have the patience necessary to answer innumerable questions.

Third.—Games with Balls, Squares, Triangles, etc.—Another "game" for developing the sense of touch with materials other than fabrics is played in the Casa dei Bambini with solid wooden geometric forms of differing shapes—balls, squares, triangles, etc. The child is blindfolded, and pulls these things, one at a time, out of a bag, identifying them solely by fingering them over. In the home this can be "played" with any material at hand with which the child is familiar. He can be blindfolded and try to identify objects in a miscellaneous heap on the table before him, consisting of toy animals, spoons, forks, brushes, combs, dolls, trays—anything in the room which will not hurt him, and is not breakable. Very little children always experience the greatest joy in thus proving that they can see "with their fingers."

EXERCISE TEN

Training the sense of hearing

Sound Boxes.—But the sense of touch is not the only one of the child's five senses which can be improved by direct training. The sense of hearing is greatly developed and made more serviceable for after years, if given reasonable practice. The Montessori apparatus provides the wooden Sound Boxes, filled with different substances —sand, gravel, flaxseed, stones, etc., which give out sounds differing in quality and loudness, when shaken. The child's attention can be thus fixed, for the first time, on a definite attempt to distinguish between loud and low noises, as he shakes these little boxes close to his ear, and attempts to arrange them in order according to their degree of noise.

In all probability, the child has heard noises of this character, but he has not had an opportunity to compare or to contrast such noises. This exercise affords an opportunity for such discrimination. As a rule, the children take a great deal of interest in this simple exercise and they show a marked difference in their ability to discriminate between the various substances.

Supplementary exercises and "games"

But this simple exercise needs to be supplemented by other "games" which fix the attention on sounds. These can be devised most easily with "hide-and-seek" games. The mother hides and blows very softly a little horn, by means of which the child traces her; or she calls the child's name in the lowest possible whispers, as he, blindfolded, tries to locate her in the room by his hearing. Any of the common children's games, "blindman's buff," "still-pond-no-more-moving," etc., played with a blindfold, are excellent exercises for the same purpose.

Out of doors, long-distance calling may be used for this purpose, to accustom the child to determine the direction from which any noise comes.

As to musical sounds, most children who are young enough for this Montessori training are too young to distinguish pitch at all accurately. Of music they receive practically nothing but rhythm, although they are fond of marching to a tune which has strongly marked time, and this is a good exercise for them, in its place.

EXERCISE ELEVEN

Preparatory exercise for teaching the child to write

Plain Geometric Insets.—Very soon after the child's first introduction to the Montessori apparatus, he can begin his use of the Plain Geometric Insets. These sets consist of a six-drawer cabinet, thirty-six geometrical insets, and a pattern in an adjustable frame, making possible any desired combination of forms. The insets are made of pieces of smooth wood, painted blue, cut in different shapes, and with a little knob-like handle in the center. These insets fit into holes or openings cut in a rectangular natural colored piece of wood. The first of the series of six drawers contains insets of strongly contrasted forms; the second drawer contains a series of six Polygons; the third drawer, a series of six Circles, diminishing in size; the fourth drawer, a series of Quadrilaterals containing one square and five rectangles; the fifth drawer, a series of six Triangles, and the sixth drawer contains Oval, Ellipse, Flower Forms, etc. These have such a vital part to play in the training of the child to write, that the mother should be especially careful in the way they are used.

The entire thirty-six different shapes should not, of course, be put before the child at the beginning but only a drawer of the most strongly contrasted shapes—triangles, oblongs, etc. He should be taught at the very start (as in the case of the solid geometric insets) to aid his sight by touch. While he holds the inset by the little knob with his left hand, he traces the outline of the inset with his right forefinger, and from left to right, or in the direction in which writing is done. Then, while still holding the inset, he traces around the outline of the depression into which he thinks the inset he holds would fit. It is quite important to establish this habit of tracing the outline with his fingers, as it has a vital bearing on learning to write.

As the child masters the tray of the more simple forms so that he finds it easy for him to place the insets in the corresponding opening, the less simple forms should be given him, a few at a time. After learning to distinguish between a triangle and a circle quickly and accurately, the next day he should be given two triangles and two circles of different sizes, to sharpen his sense of shape and dimension. After a time, he should be able to replace in the correct openings six triangles of differing shapes, and six circles of differing sizes.

It is perhaps well to give here the warning which can never be too often sounded—not to force the child's attention to this, any more than to any other problem. When mental fatigue sets in, and at the least sign of inattention, the tray of insets should be put away and some romping game outdoors played, or a quiet story told.

EXERCISE TWELVE

Replacing the insets blindfolded

When the insets have become old friends, it is well to try blindfolding the child, and setting him the new problem of replacing the geometric forms by the sense of touch only. Here it is well to go back again to first principles and to begin once more with the easiest forms, until he grows accustomed to depending on his touch only. This is splendid practice, and a child who has had it grows astonishingly keen in his capacity to take in accurate impressions from his finger-tips. How valuable the ability to work without looking at what is being done, can be estimated from the experience of almost any variety of hand-worker. The old grandmother who knits without once looking at her needle can work all day long without a particle of fatigue, while the knitter who needs to be verifying each stitch by her eyes soon tires them out and must either stop working or suffer a violent headache. The stenographer who writes by touch has a tremendous advantage over the other who needs to use her eyes.

Dr. Montessori lays great stress upon the value of the work with these wooden geometric insets. They are so practical and at the same time so fascinating that the child learns a great deal in working with them. The primary object is that the child should learn form; that is, that he should see the difference between various objects. Ordinarily, this is a very tedious task for the child, but Dr. Montessori, by means of her self-correcting apparatus, has made a game that appeals to normal children. The mother should not be at all surprised if after a few weeks of play with this apparatus the child should begin to point out various objects in his environment, comparing them with certain insets he has learned to know.

EXERCISE THIRTEEN

WITH WHICH THE CHILD'S COMPREHENSION PASSES FROM SOLID OBJECTS TO THE PLANE LINE, FROM THE CONCRETE TO THE ABSTRACT

Plane Geometric Figures Reproduced in Three Series of Cards.—After the final mastery of the geometric insets, the child is given a series of cards, representing the same forms as those of his insets. In the first of these three series, the forms are cut out of solid blue paper and mounted on white cards; in the second, the forms are cut out of heavy line drawings and mounted on the cards, and in the third, the outline or form is represented only by a thin blue line, such as is drawn by any pencil.

The child mixes up, say six or eight of these cards, and six or eight corresponding insets, and then sets himself the task of putting the insets on the corresponding card. Here he has not the sense of touch to guide him, and learns gradually the meaning of the line, passing from the solid blue form to the form merely drawn in outline.

After the child has played with these various cards for some time he will have acquired a very definite idea of symbolism. That is, it will be comparatively easy for him to understand how a series of lines can stand for an object. Ordinarily, it is not difficult for the child to see the connection between a photograph and an object, but with an abstract line it is entirely different. What is there in the symbols c-a-t that would connect them with a cat? Dr. Montessori believes that the child should understand symbolism before the alphabet is taken up.

EXERCISE FOURTEEN

INVOLVING THE FIRST USE OF THE PENCIL

Plane Geometrical Insets Made in Metal.—And with this recognition of the line, might go very well with the average child the beginning of the use of the pencil. This exercise is done with the Plane Geometric Insets made of metal. Accompanying the metal insets in the formal Montessori apparatus are two wooden trays with sloping tops, large enough to hold three of the metal insets and intended to be placed by the child on his own table. It is, of course, unnecessary to point out that a small table and chair, just the right size for a child, are essentials in Montessori or any other right training for childhood.

The child puts a piece of white paper on the wooden tray or on his own table, then places the square inset over the paper and lifts out the central piece by its little knob. The white paper shows through the hole in the shape of the inset. The child is given a pencil and is shown, once, very briefly and simply, how to hold it and how to trace around the outline of the inset. He is apt to make bad work of this at first, as this is the very first use of the pencil, but his interest almost certainly carries him through the first difficulties. To begin with he simply traces the outline, lifts off the metal inset and admires the design on the paper beneath. The metal edge of the inset is a guide to his staggering little pencil and before long he will be able to make a good, clear outline, joining the ends neatly.

EXERCISE FIFTEEN

THE USE OF COLORED CRAYONS

First Lesson in Drawing.—When this has been accomplished the child is furnished with a box of colored crayons, and invited to fill in the "picture" he has made with strokes of his crayon. The fact that he is working in color stimulates his interest and few children need more spur to advance than the simple permission to use the crayons. At first, and for many days, his efforts to fill in the outlines will be ludicrous in their inaccuracy. He should not be corrected, and should be allowed to pass from one form to another as often as he pleases, being supplied with an unlimited amount of paper and leisure for this new undertaking. Little by little, as he works at this accomplishment, along with other Montessori "games" he begins to "get the hang of it," in our vernacular phrase. The lines become more and more parallel, fewer and fewer go wildly outside the line enclosing the outline, and finally the geometric form is shown in color on the white paper almost as though it had been printed. This advance is not rapid, however, in the case of most children, and nothing should be done to hurry it. Occasionally a child gets tired of the whole process and will play with other things for several days without recurring to his "drawing," although on the other hand, some children are, from the first so fascinated by the problem that they can hardly let it alone. The child should be allowed to choose his own time for working at this and to spend as much or as little time over it as he wishes, although if there seems any likelihood that he has really forgotten it, his attention may be called to it again.

EXERCISE SIXTEEN

Training the eye; the matching of colors

Color Boxes and Color "Games."—At about the same stage of development that the geometric insets are first given to a child, the color boxes can be shown him and the color "games" begun. The color boxes are sets of spools, wound with silk of varying shades, eight of the main colors, and eight shades of each. At first the child is shown only two strongly contrasting colors, red and blue, for instance. The name is pronounced clearly and distinctly, holding up the corresponding color. When the child has grasped this the colors are allowed to lie on the table and the mother says, "Give me red," or "Give me blue."

When the child has progressed this far (this may be the next day, or even two or three days after the first introduction) the teacher or mother holds up a spool and asks, "What is this?" When the child can answer correctly, "blue" or "red," he has thoroughly learned those two colors and can progress to another one. When the eight main colors have been learned in this way, the child can begin to match them. Four spools are laid on the table, two red and two blue (of course of exactly the same shade). The child picks out the two red ones and lays them side by side, and then does the same for the blue. From this he can go by degrees until there are sixteen spools on the table, eight pairs, which he must put together.

EXERCISE SEVENTEEN

Differentiation of colors

After the matching has been mastered, the next step is to differentiate between light and dark shades of the same color, dark red and light pink, for instance, or dark and light blue. This goes in pairs at first also, but little by little, as the child's accuracy increases, he may go up to the eight shades of the different colors. Some Montessori children become so proficient that they can "carry a color in the eye," as it is called. That is, they can look at a spool of a certain shade of purple, go across the room to a pile of spools and pick out the color matching it.

Games and practical application in matching colors

With these color spools, a variety of "games" can be played, which any mother can invent, according to the number and age of the children wishing to play. They are all variations on the principle which is used in the game of "authors," and can be made simple or hard as circumstances direct. Furthermore, as in the treatment of fabrics, the child's attention is awakened to the presence of color in everything about him, and his interest aroused in the problem of determining the color of the carpets, curtains, dresses, etc., which he sees in his every-day life.

The reason for using these little spools upon which the silk is wound is that the child's attention is primarily directed to the color and not to the object.

The spools in themselves are very unattractive while the richly colored silk is just the opposite. Silk thread is used because it gives a deeper, richer color, at the same time is more practical and makes possible the various gradations.

Too much importance cannot be placed upon the developing of the chromatic sense in early childhood. If the child at an early age acquires a deep interest in shades and tints of colorings, he will not only be able to appreciate his environment much more, but this knowledge and appreciation of color will be of inestimable value to him in later years.

The ethical element in such training is also very important. If the child is taught to see the beautiful and to appreciate it even in his early years it must have a marked effect upon his later life.

EXERCISE EIGHTEEN

Special physical and gymnastic exercises for the young child

In connection with all these exercises with the Montessori apparatus there are a number of other exercises, chiefly gymnastic, which should be constantly in use. As soon as the child can walk at all, every effort should be made to teach him further and more definitely the art of equilibrium of his body. When we walk we continually balance our weight so that we do not fall down, and more accurately and unconsciously we do this, the better we walk. Now, bodily poise is one of the very important factors in bodily grace and even in strength, certainly in comfort.

The chalk line exercise

In the Casa dei Bambini the exercise used for this need is arranged very simply by means of a long chalk line drawn on the floor. The children are invited to see how accurately they can walk along this line without stepping off. At first the little tots cannot manage this at all. Later they learn to walk very slowly along the line, and later, when they are four or five, to run as swiftly as deer along this line without swerving once from it.

Walking the two-by-four

A modification of this exercise can be arranged out-of-doors by laying a long piece of wood known as a "two-by-four" down on the ground and permitting the child to try to walk along it without falling off. He is usually ready to spend a long time at this exercise, and to return to it repeatedly. The benefit derived from this is beyond calculation.

Rope-balancing and walking backward

If a length of rope can be hung up where the child can reach the dangling end of it he will devise for himself a variety of exercises in balancing which will greatly increase his mastery of his body. Another exercise of great value for little children, is in walking backward. At first they need to be helped, for their little brains are so unused to reversing the processes of ordinary walking that they are quite helpless, but after a comparatively short time, they learn this new trick and practice it with delight. If possible every small child should have a little swing, just the right height for him, and a tiny spring-board ending over a pile of hay or anything soft, from which he may jump and learn to balance his body in the air.

THE BABY BALL

Most children of three are too young to have the least capacity for throwing or catching a ball, but if a ball is hung on a long string and tossed to them, the string retards the motion just enough to make it possible for their little brains to set their muscles in action, and they will play with great joy and profit for a long time, at this variety of "baby-ball."

ENCOURAGE CHILD'S INVENTIVENESS

Of course the greatest freedom should be allowed for any exercise (not injurious to the child) which his invention hits upon. The action so common among little children of throwing themselves on a chair or stool and kicking their swinging feet in the air is an excellent exercise for the muscles of the legs and should never be discouraged. To climb up and down a short length of ladder, with the rounds set at a distance appropriate for short legs, is also very beneficial.

SHOULD SHARE HOUSEHOLD WORK

A child who is being trained in the Montessori system should also, as soon as it is at all possible, begin to share in the work of the household. If he is provided with a small broom and dustpan, there is no reason why he should not keep his room fresh and clean, and also clean up any litter of paper or dirt which he makes in the course of the day. Setting the table is a singularly good exercise for a little child although of course it is enough to begin with, if he does only a small part of the whole operation.

The important element should be that what he does, he does entirely himself. If he is set to put a spoon at each place, he should be left (after due explanation as brief as possible) to wrestle with the problem and to solve it with his own unaided invention. Later he can be given all the silver to put in place, and as he learns in his Montessori exercises, *mastery over his muscles*, can be entrusted with china and glass at four and five years of age, which an untrained child of ten or eleven would be almost sure to break.

SUMMARY OF CHILD'S ATTAINMENTS IN THE MASTERY OF HIMSELF AND HIS WORLD

But to return to those formal and ingeniously devised "play-things" which so wonderfully and insensibly lead the little child to a mastery of his world and himself, let us suppose that the child for whom the box of apparatus came into the home, has now been "playing" with the different pieces of apparatus described for about three or four months, longer if he was only three when he began, a shorter time if he was older. He has learned to replace the geometric insets blindfolded by the sense of touch only, to distinguish fabrics and materials, to build the Tower, the Broad Stair and the Long Stair, to match colors, to distinguish between noises of varying intensity, to balance himself deftly, to manage a glass of water. His mother may very well consider that it is now time to begin to teach him the beginning of reading and writing.

EXERCISE NINETEEN

LEARNING TO WRITE AT THE AGE OF FOUR

Sandpaper Letters.—The child is told that there is a new game to play and the little box containing the famous sandpaper letters brought out. This alphabet is composed of letters in plain, round script, cut out of black sand, or emery, paper and pasted upon smooth white cards. Here at once the child's past practice in learning about objects through touching them, as well as looking at them, comes into play. He is shown a letter, the mother pronounces the sound of it clearly, and shows him how to trace around it with his finger in the way one would write it. He should touch it very lightly, as he has been taught to do with all his work, and should, at first, only trace the letters when some one is watching him, to make sure he does not do it backward, or upsidedown. Make sure that he knows the vocal sound of the letter or figure he is tracing. Most children of three-and-a-half or four have seen so much of writing among the adults of their acquaintance that their curiosity is deeply aroused as to the mysterious process and they are delighted with the prospect of learning something about it. They need, as a rule, no further incentive than the statement that this is the beginning of their learning how to write.

TESTING THE CHILD'S COMPREHENSION

As soon as a few letters are learned, the teacher, or mother, should make sure of the child's grasp of them in the same way she tested his knowledge of colors. She lays down four or five on the table and asks for a certain one. "Give me 'a,' please," or "Give me 'b.'" When the child can do this quickly and surely she next holds one up and asks him what it is. When he can identify those first letters he can be allowed to pass on to others; it will not be long before he has mastered all the letters.

RECOGNIZING AND SPELLING WORDS

Before that time, however, if his interest in the process is lively, he can begin to recognize words, and to compose them. If he has learned "p" and "a" he can compose the familiar word "papa," and will, in most cases do this of his own accord if his attention is called to the pronunciation of the word. If his mother says "How would you make this word?" and then pronounces it very slowly, separating the sounds distinctly, the child will analyze the word into its component parts. "It begins with 'p,'" she says, giving the phonetic sound and not the name of the letter. Of course the child reaches instinctively for the "p," and thereafter recognizes the sound of "a," puts the two together and looks on delighted at the first word of his composition.

EXERCISE TWENTY

LEARNING TO READ THE REGULAR MOVABLE ALPHABET

At this point the child should be presented with the Regular Movable Alphabet of cut-out script letters in stiff paper.

These come in two large, flat, pasteboard boxes with partitions dividing the same into separate compartments for each letter. There are four or five duplicates of each letter, making a like number of complete alphabets and, of course, additional letters can easily be made at home, if more are needed. These letters are not pasted on cards, like the sandpaper letters, and are easily handled and arranged as the child wishes, and with these begin his composition and recognition of words. He is not troubled, as in the old system, by the difficulty of forming the letters, as all he has had to do is to take them from the compartments and make words with them, long before his little fingers have acquired the ability to handle a pencil surely and accurately.

PRACTICE WORDS

Of course English-speaking children have a much harder time to compose words from letters than Italian children, whose language is phonetically written. The English-speaking mother who attempts to teach her own child how to write and read, will infallibly become a convert to the simplified spelling idea, but, since it is out of the question for the present to change the wild insanities of English spelling, we must possess our souls in patience and exercise as much ingenuity as possible in introducing the little one to the life-long burden of an illogically spelled language. It is well for this purpose to choose for the first words, the very simplest ones, like "rat," "pin," "hen," "mama," "papa," "dog," etc., words which are not only within a child's natural comprehension but which offer no difficulties in the way of consistent spelling. When the inevitable difficulties occur, the best that can be done is to rely on the naturally quick memory of childhood, and to fall back on the helpless statement that "it's spelled that way because that is the way it's spelled." However, there is, even in English, quite a vocabulary of sensibly spelled words, which the child can acquire as a working beginning.

EXERCISE TWENTY-ONE

REVIEW EXERCISES WITH APPARATUS ALREADY MASTERED

Although he may from now on, "play" with the movable alphabet, the use of the sandpaper letters should be steadily continued, causing him to trace them, *as they are written*, several times a day, if his interest allows. It is almost certain that he will ask to do this, as touching the letters brings home their form to his little brain much more certainly than merely looking at them. Sometimes children fail to recognize a letter when they look at it, although they can identify it perfectly after their fingers have traced it. This, being one of the essential steps in writing, must not be neglected.

At the same time that these exercises are being repeated as often as the child's interest makes possible, the exercises with "drawing," that is, tracing the outline of one of the geometric insets on the paper and filling it in with colored chalk, should also be steadily continued, for this *tracing teaches the child to use the pencil.*

THE EXPLOSION INTO WRITING

We quote from *A Montessori Mother* a paragraph describing the final success of these three exercises, "All these processes go on, day after day, side by side, all invisibly converging towards one end. The practice with the crayons, the recognition of the sandpaper letters by eye and touch, the revelation as to the formation of words with the movable alphabet, are so many roads leading to the painless acquisition of the art of writing. They draw nearer and nearer together, and then one day, quite suddenly, the famous 'Montessori explosion into writing' occurs. The teacher of experience can tell when this explosion is imminent. First, the parallel lines which the child makes to fill and color the geometric figures become singularly even and regular; second, acquaintance with the alphabet becomes so thorough that he recognizes the letters by sense of touch only; and, third, he increases in facility for composing words with the movable alphabet. The burst into spontaneous writing usually only comes after these three conditions are present. It is to be noted that for a long time after this explosion into writing, the children continue incessantly to go through the three preparatory steps, tracing with their fingers the sandpaper letters, filling in the geometric forms and composing with the movable alphabet."

Cautions to be observed

There are several cautions to be expressed about this whole process of teaching a child to write and read by the Montessori method. The most important one is against hurry. Even more consistently and steadily than with the rest of the apparatus, the child's natural gait ought not to be in the slightest degree hastened by urging from outside. He will go, in any case, so very much more rapidly, easily and surely, than children in school, that urging him is not necessary. The temptation with a bright quickly adaptable child is to attempt to "make a record." The mother should always act deliberately, she should take the greatest pains to be sure that the child understands every step before he passes on to the next and that he has thoroughly mastered one process before he is allowed to progress to another more complicated. Above all, she should refrain from forcing the child's attention in the slightest degree.

EXERCISE TWENTY-TWO

Undirected work; maintaining the child's normal or everyday life

All the time that this work with the drawing and filling in of geometric forms, the tracing of the sandpaper letters and the composition of words with the movable alphabet is going on, the child's usual normal life should be continued. There should be plenty of *undirected* outdoor play, where the child's natural inventiveness has scope, "hide-and-seek" games, "tag," etc., with plenty of fun in the company of other children should be encouraged. There should be much reading to him of well-selected stories and poems suited to his age; with long hours of sleep, and a certain amount of helpful service about the household work. A "Montessori child" does not by any means signify a child who devotes most of his time to exercises with the formal apparatus.

Plant and animal pets

He should have, if it is possible to arrange this, a plant or two of his own (even at the age of three) and a pet of his own, preferably a good-natured kitten, for he is rather young as yet for a puppy. He should assume the real responsibility for these plant and animal pets, caring for them himself. Later, he should have a little plot of ground, and learn from actual experience the wonder of growth from seeds.

How the child learns self-care

He should have in his own room, or in a corner of another's (if he has no room of his own) a tiny washstand, with a little bowl and pitcher, light enough for him to handle, and a mirror hung low enough for him to see if he has succeeded in getting his face clean. He should be allowed the time necessary to wash his face and hands, and should be taught to empty the bowl and to keep his washstand neat and clean.

As soon as possible, he should be encouraged and allowed to dress himself, his clothes being made with this in view, although there must always be some buttons which three and four-year-old fingers cannot reach, and should assume the responsibility of putting away his own clothes and knowing where they are. People who have struggled with older children on these subjects will be surprised to note how naturally and easily a little child will assume these helpful and desirable habits. The important point is to "catch him young," before he has learned bad habits of irresponsibility and sloth. Of course, there should be, as far as possible, the greatest amount of regularity and routine in the little life. He should eat his meals at regular hours, feeding himself and sitting at a low table; and he should take his naps regularly.

And this simple, industrious, tranquil life, with no excitements of joining in adult "pleasures"; full of profitable "play" which is educational, and permeated with a sense of responsibility on the child's part for the conduct of his own life, *is the Montessori life* for a child between two and seven. It is not enough that he construct the Tower, and the Long Stair, and learn his sandpaper letters perfectly; he must learn to be a self-dependent, self-respecting, self-trusting citizen of his little world.

EXERCISE TWENTY-THREE

FIRST STEPS IN ARITHMETIC

Counting Boxes and Sandpaper Numbers.—We have now to consider the question of arithmetic and the Montessori application of the subject to the child of the average American home. There is a prejudice about presenting mathematics to children under six, no matter how simply it may be arranged. But experience in the Casa dei Bambini has shown that children over three take a lively interest in the sequence of numbers, and in some of the simpler processes of arithmetic, if those processes can be presented to them in a sufficiently concrete form. The Montessori apparatus for this purpose is very simple, and can be supplemented by several other devices, easily obtained in any home.

These counting boxes comprise two small boxes, with five compartments or divisions in each. Accompanying the two boxes are fifty smooth, round sticks, exactly alike, and a set of numbers from 0 to 9, cut out of sandpaper and pasted on white cards. The counting sticks give the child a concrete basis for the abstract names of the numbers, and he learns to associate the symbol with the concrete object. At first the child does not play with the sandpaper numbers. These are removed from the boxes and he but wrestles with the problem of oral counting, using the sticks. One good way to begin is by arranging one of the boxes so there are no sticks in the first compartment, one in the next, two in the next, three in the next, and four in the last. This exercise is, of course, for a very little child who has no idea of the definite sequence of numbers, or of how to determine how many objects he holds in his hand. The other box is then emptied of all its contents and given the child, with an ample supply of the counting sticks, and he is invited to make his box exactly like the one his mother has arranged. Most children can, even at a very early age, quickly put one stick in the second compartment and two in the next. Here frequently, at the very beginning, there ensues some mental confusion, and much eager gazing at the three sticks in the box arranged by the mother. Anxious attempts are made by the child to lay an equal number in the next compartment of his own box.

The mother should not help in this process. It does the child no good if she interferes and does it herself, or corrects his mistake. If he has arrived at the age when his brain can master this simple arithmetical idea, he will ultimately solve the problem and place the proper number of sticks in each compartment. If he has not yet arrived at the right age or state of development, he will not readily take in the significance of anything his mother may do, seeking to aid him. If he repeatedly performs this exercise incorrectly, or shows signs of mental fatigue, the boxes should be removed, and the attempt postponed until a later day.

The mental growth of children at this age is so astonishingly rapid that sometimes a child will be able easily to solve a problem only a week after he has found it perfectly impenetrable. It is far better to trust this principle of growth than to attempt to urge the child to put forth powers which he does not as yet possess.

Beginning to Count

As soon as he can complete the series up to four, he can go on, one at a time, to complete the series up to nine, as shown in the illustration; and then, if he is the normal child, with a wide-awake, intelligent, curious mind, he will be observed "counting" everything in sight. He is delighted with his new acquisition, and employs it on all the material at hand.

EXERCISE TWENTY-FOUR

The Sandpaper Numbers Are Added

Now is the time to bring out the sandpaper numbers. He is taught these just as he learned his letters, one at a time, and following the three regular steps. First, the mother guides the little forefinger over the rough sandpaper as the number would be written, at the same time pronouncing the name of the number, slowly and distinctly, and adding no explanations. She should refrain from wordy comments simply saying, "8," and show the little fingers how to trace the outline. Then she should lay several down on the table, and ask the child, "Give me '7,' or "Give me '2,' please." When he has mastered this she should then hold up a card and ask the child to tell her what it is. When he can do this accurately, he has mastered his numbers.

According to his age and capacity, this may take him two days, or two weeks. The next thing to do is to teach him to connect them with the right number of objects. And here the counting boxes come again into play. He should arrange the series, and place the right number in each compartment. The mother will be surprised to see that even after mastering the names and looks of the number and the sequence in the number boxes, the average child finds it quite an intellectual effort to put the two things together in his mind. He will need plenty of time and quiet to struggle with the new problem, and if it is too hard on the first trial, the number boxes should be taken away without comment, and some other "game" suggested.

EXERCISE TWENTY-FIVE

An Arithmetical Game with the Long Stair

Another arithmetical game is played with the Long Stair. The stair is arranged in sequence and a cardboard number corresponding with the number of rods in the section is leaned up against the section; "1" against the section with only one rod, the "2" against the next one, and so forth.

A Game with Money

About this time, or perhaps a little earlier, it is well to begin to teach a child the significance of money. He is always interested in this, and will play with it endlessly, and study the possible combinations to be made with it, if they are suggested to his mind. It is better, if possible, to have new money. If this cannot be managed, the coins should be thoroughly cleansed before the child plays with them. The mother should teach him the names of the different coins with the same three steps used in teaching him the names of the letters and numbers; that is, first tell him the names, slowly, one or two at a time; then ask him for a given coin; then point to a given coin and ask what it is called. At first the little child likes, as a rule, simply to sort out the money into the right piles, all the pennies together, all the nickels, all the quarters, etc.

Arithmetical game with counting sticks

An interesting "game" which can be played with numbers, if there are two or more children together, is the following: A certain number of the counting sticks, or any other objects such as clothespins, stones, spoons, coins, etc., are placed on the table. The mother then holds a bag containing the numbers up to ten. Each child draws a number at random, and, without showing it to his companions, goes back to his seat. When all have drawn their numbers, each child goes up to the table and selects from it the number of objects corresponding with the number hidden in his hand. He carries these back to his place and arranges them in order, and waits for the mother or teacher to come and verify the correctness of his counting.

Teaches self-control

This simple game, which would not amuse older children for a moment, is of inexhaustible interest for little ones, and has a various and complex influence on them. There is a considerable amount of self-control involved in their taking only the number of objects indicated by the number they have drawn, since every child's instinctive action is to grab all he can hold and carry off his prize in triumph. The mother should explain that this spoils the fun of the game, which consists in fitting the mysterious written sign to the number of objects chosen. Another conception which is firmly settled in the child's mind by this and other similar "games" is the abstract idea of "zero," since the child who draws zero selects no objects at all.

Game with sandpaper numbers

Another arithmetical game which can be played with one or many children is played with the sandpaper numbers, or any large numbers, such as could be cut out of old calendars. The mother or teacher holds up a number and says, "Come and give me this many kisses," or "Bring me this number of pennies."

Game with movable alphabet

A similar game can be played with the movable alphabet, with older children, who have learned the beginnings of reading. The mother constructs the word, say for instance, "pin," and, pointing it out to the child, says, "Bring me this, please." The child who is first to read the word and select the article, wins. When several children of the same age and acquirements play this together, the fun, and intensity of interest, and consequent sharpening of wits, form an invaluable exercise.

Hide-and-seek with movable alphabet

A game of hide-and-seek can also be played with children who have begun to recognize words formed with the movable alphabet. The mother constructs, in different parts of the room, different simple words which the child has already seen, such as "pig," "hen," "dog," etc. The child is out of the room while this is being done, and is called back to be told, "I hear something grunting." He then rushes about, peering under the chairs and on the table and window-sills, rejecting all other words he finds, until he comes triumphantly to "pig."

WHAT IS WRONG IN THESE PICTURES?

In each of these pictures the artist has purposely made some mistake. Look at the pictures carefully, and see if you can discover what the errors in them are.

DISCIPLINE AND OBEDIENCE

There is one phase of the Montessori idea which needs more explicit expression than it is apt to get in general descriptions of the system. That is the question of discipline and obedience. Those two subjects are so vital and so tragically misunderstood by most of us, that it may be well to go a little more deeply into the discussion of them.

Intelligent obedience

The first thing to do, in the consideration of the obedience of children, is to differentiate clearly in our minds between the obedience that is desirable for an animal, and that which is desirable for the young of the human race. We are apt to be confused here, and to have a misunderstood notion that children should obey, unquestioningly, passively, with no volition of their own, as does a well-broken horse. But such unquestioning obedience, as a moment's reflection will show, is a very dangerous mental habit for a child to acquire, as well as a very difficult one to force him to acquire. The horse may obey unquestioningly some human being; he will always have some human being set in authority over him. But in a very few years, as human life goes, the child will be grown; will no longer be subject to the authority of parents, and must in turn be able to secure the obedience of others. It is essential, therefore, that he shall begin to be a human being—that is, to obey intelligently—as soon as possible. What do we mean by the phrase "obey intelligently?" We mean he must obey, not because some one has told him to and will punish him if he does not, for that is the obedience exacted of the animal; but he will obey because the command is a reasonable one, which his reason tells him it is necessary to obey.

The basis of parents' authority

Our children should understand that their duty is not to obey our personal wishes, because we happen to be their parents, but to obey eternal laws which we represent and expound and enforce. To take an instance, familiar to all of us, which comes into our everyday experience: Children should not, any more than they can help, be "messy" over their meals; should not spill food on the tablecloth, or on their clothes, or be unpleasant in their way of eating. Why should they not do these things? Simply because their parents forbid it? Not at all. Because it is their duty, as members of a community, to make the common life as agreeable, as easy, and as economically conducted as possible. Their parents' duty is not at all to cry, "You do it because I say so!" but to explain reasonably the underlying grounds of conduct, to allow a reasonable time for an understanding of the principle to reach the child's brain, and then to be unflinching in their police duty of enforcing obedience—obedience not to themselves, but to a law, which they must obey as well as the children. If there is no such general broad basis for a command given to a child, it is an unjust command, and should not be issued. No child should be forced to obey a whim of the parent, but only, some modification of one of the general laws which he will need to obey when he is grown up.

The management of the very young child of unreasoning age

Now, of course, it is impossible for very little children to make this distinction. Babies under eighteen months must be forced to obey, if the occasion rises, as other little unreasonable animals are forced, by sheer physical compulsion. But, as this is a very bad method of obtaining obedience, the occasions for requiring obedience should be sedulously avoided, as much as is reasonably possible, during this animal-like period of the child's growth. No one thinks of requiring obedience of a week-old baby, and yet he is in many respects just as capable of being obedient as many a year-old child.

In general, with very young children, the method of procedure should be to so arrange their lives that there shall be few needs to issue commands. A child who is kept quietly at home, playing with objects designed for his use, who is not "shown off" to adults, who is not forced into such cruel situations as enforced participation in adult life, like traveling on the cars, going to church, or to shops, or on the street cars, or asked to entertain a company of idle elders, will rarely be insubordinate or think of such a thing as disobeying for the simple reason that the things asked of him are within his capacity to do. On the rare occasions when such a crisis arises, it is best frankly to treat the little creature like a speechless animal, which he is, and enforce obedience to something necessary.

As soon as he begins to be able to understand simple statements, the reason for various commands given him should be explained to him. One result of this rule is apt to be that fewer commands are given, as they are often seen to rest upon utterly unreasonable grounds. The child should be trained, first, to obey promptly, and then to expect an explanation of the action. In most cases this careful clarifying in his mind of the grounds for action, results in a most satisfactory régime of reasonableness. Suppose, for instance, that a child is seen climbing upon a chair before the side board in the dining-room. His mother should not call out to him simply, "Come away from there!" but should explain to him that it is dangerous for him to handle the glasses, standing in rows on the top, because he would be apt to break them. If the child then asks to be allowed to play with the spoons in the drawer, there is no reasonable grounds for refusing that request. He has made a concession, and has learned self-control and obedience in refraining from touching the glasses, and his mother has, if she is alert-minded enough to learn a lesson, taken note that her command, "Come away from there!" was not exactly fitted to the case. She should have analyzed the situation more acutely, and see that she need not forbid a harmless amusement to the child because it happened to be in proximity to a potentially harmful one. Such frank explanation and mutual concession are most valuable and vital elements in the harmonious relations of parent and child, and do more than anything else to prevent that bitter rebellion against authority which so often saddens the adolescence of children with strong wills and a keen sense of justice.

The mother should make the most careful distinction between the conscious, willful action of a child, and the sort of wild irritability which results in "naughty" actions, but which is the result itself of nervous fatigue, due to injudicious treatment. In the Casa dei Bambini, on the very rare occasions when a child is "naughty," he is treated as a "sick" child; is put off in a quiet corner of the room, allowed all the toys he wishes to play with, is soothed and petted, allowed everything but (this is the important point) to play with the other children. In a short time this reduces the most unruly child to submission. But in an ordinary home, with only two or three children, the "naughty" child is not privileged, like the Italian child in the Montessori school, to see constantly before him the precious example of the orderly, peaceable, industrious behavior of thirty other children. The principle, however, holds. Nine times out of ten, the "naughty" child *is*, in all sober reality, a sick child, or at least a very tired child. It is hard for adults to realize what a nervous strain it is, for instance, for a child of three to see strange faces for a few hours.

Should not discipline or try to reason with a child when nervously excited

The only thing the mother can do in such a case is to remember that the child is not himself when nervously excited. There is no use trying to "reason" with him, or to discipline him, or arouse his better nature. For the moment he *has* no better nature! He is nothing but jangled nerves. A tired or excited young child should never be asked to exercise self-control; there should be no occasion for it. The only thing to do with him is to quiet him as soon as possible by purely physical means. If he is hungry, get him something, very easily digested, to eat; slip off his clothing, give him a warm bath, if possible, and lay him down in a comfortable bed, in a room not too light, with *plenty* of fresh air. When he has slept and rested, he will have "come to himself," and the necessity for punishment will be past. He will, as he always does when he is in good physical condition, *desire* to be a good child. There will be something there for the mother to work with. Even if he has had no special excitement, there may be times, in the life of an especially nervous child, when his vitality is at a low ebb, and the regular routine of life is too much for him. If he shows signs of nervous irritability, snarling and snapping, or crying at nothing, he should never be reproved. He should be put to bed, not at all as a punishment, but with the tenderest affection and the most solemn pity for the poor little sensitive creature. If there is in this prescription of rest for nervous fret, no hint of punishment or shame the child will not resent it, but will soon learn to yield himself up to the soothing influence.

How to avoid a "brain-storm"

If, when several little children are playing together, the mother hears one begin to speak in a loud, excited voice, and to have nervous, disorganized motions, such as knocking the playthings about, she should come up quietly to the group and remark calmly that "Johnny is evidently too tired to play any longer. He'd better go and rest for a time, until he feels better." Then he is led away, very gently. There should be the utmost care not to seem to use this as a chastisement. His face and hands should be washed in cool water (there is very apt to be a slight fever present when nervous irritability sets in), his clothing loosened, and he himself laid on a bed in a quiet room. This treatment has, in addition to the invaluable physical effect, a very strong moral one. The gentleness, the peace of the room, the utter isolation, the inaction—there seems nothing left for the child to battle with, nothing for his "naughtiness" to feed upon.

Children do not enjoy the miserable unhappy excitement of being naughty, no matter what our misunderstanding reading of them may seem to indicate. And if they have had a fair experience of a sure escape form the "brainstorm" of a fit of insubordination, they are very apt to resort to it of their own accord. If it is evident that the child cannot be sleepy, for instance, only a short time after a nap, another calming expedient is to take him gently away from the others to a quiet place outdoors, where he is left to play in solitary proximity to the bosom of Mother Earth.

But of course this remedy cannot be applied, if the nervous fit comes on while the mother is pricing lace in a department store and the child hanging to her skirts, or if they are at an "amusement park," with bands braying and tooting about them, and crowds of excited pleasure seekers noisily going their way.

This is another reason for never taking children away from the quiet home life, except to some equally quiet spot out-of-doors.

This rule may be relaxed, of course, as the children grow older, but it should be relaxed very gradually, with the fewest possible breaks in the tranquil and unchanging life.

NECESSITY FOR CONSTANT ACTIVITY IN EARLY CHILDHOOD

The final lesson we American mothers have to learn from Dr. Montessori and her wonderful success with the training of little children, is the lesson of positiveness, as opposed to negativeness in their lives. The craving for constant, unceasing activity in little children is intense. This is a normal and blessed instinct of theirs, which does more than anything to develop them. And the mother should constantly bear it in mind. Her attitude towards her little child should be as little negative as may be; she should set her grown-up wits incessantly to work to devise wise, harmless and beneficial actions for the child, not merely to forbid him unwise and harmful ones. And here the Montessori apparatus is of incalculable value. It caters with scientific ingenuity to the need for action of the small child, and relieves the mother's inexperienced brain of a great part of the strain of inventing suitable exercises for children under six or seven.

MONTESSORI APPARATUS NOT ENOUGH

But the Montessori apparatus, valuable as it is, is not enough. As has been said many times in the preceding pages, the mother's mind must be alert and ingenious to supplement it as the child grows. For instance, blunt pointed scissors and plenty of paper to cut are as indispensable as the geometric insets. Constant exercises in the occupations of everyday life, such as washing and wiping toy dishes and setting a small table, sweeping the floor with a small broom, learning to dust, etc., are as necessary as the sandpaper letters. If the children are initiated into these exercises young enough, before their natural instinct for action and for helpful action has been atrophied by the customary idling in early childhood, the mother will find the utmost eagerness for such activities, and not at all the lazy, shirking attitude towards them so frequently seen in older children, who did not have proper training in their early life.

The other kind of obedience, the right kind, can be attained only very gradually, for it is at least as difficult an achievement as learning the multiplication table. The child needs to begin with very small beginnings in this as in any other important activity of his life, to be asked in early childhood to obey as seldom as possible, because his life is rightly and carefully suited to his needs; to have the reason for obedience; the real, underlying philosophic reason explained to him as soon as possible and as often as necessary; never to be asked or expected to obey when he is having what amounts to a fit of hysteria; and, finally, to have his life so filled with interesting, profitable and entertaining occupations that the question of obedience enters into it very little. Through the daily experience of living a well-ordered, industrious, purposeful life, he learns, unconsciously the joys of peace and tranquility, and he comes to be as unwilling to wreck these by insubordination as his mother is unwilling to have him.

Like any other good *habit*, obedience cannot come from one or two violent efforts. It must come from a long, long continuance in the right conditions. And to secure these "right conditions" the Montessori apparatus, method and philosophy are the most potent means as yet discovered.

MEMORY TESTS ON MONTESSORI SYSTEM

What facts about children did Dr. Montessori rediscover?

What is the most important principle of her Method?

What three principles may be said to sum up the Method?

On what principles can children learn without detailed instruction?

Why should the five senses be carefully and directly trained?

What is a Casa dei Bambini?

Will little children learn useful things if not forced to stop playing?

Why is spontaneous attention better than forced attention?

Is it well to help the child with his Montessori problems?

Do little children as a rule learn best through the eyes or through the fingers?

What are some of the essentials for teaching system and order?

Why should a child learn to dress and feed himself as early in life as possible?

Why should the little child not be hurried?

Why is a very large rag doll to be especially valued as a play-thing?

Should little children be allowed to handle or play with small objects?

How can children be taught to "see with the fingers"?

What are some of the advantages of learning to do things by touch rather than by sight?

Does Montessori freedom for the child mean upsetting all order in the household or schoolroom?

Why the child needs training in bodily poise and how this can be obtained.

Shculd children be allowed to play with water? How? Why?

Should little children do housework? How?

How should the alphabet be taught?

What are the three signs by which a Montessori mother or teacher can tell when the child is nearly ready for the explosion into writing?

Should a little child have pets of his own?

What is meant by a "Montessori scheme of existence" for little children?

Should a child's life have some unvaryingly regular events?

Under what conditions do little children take an interest in arithmetic?

How should the numbers be taught?

How can arithmetic be taught by means of games?

How can the Montessori game of "Making the Silence" be duplicated in the home?

Why should a child practice exercises in immobility?

Why should a child's actions about the house be as free as possible?

How can ordinary incidents in home life be turned into Montessori exercises?

Should little children be allowed to play with books? With delicate breakable objects? Under what conditions? Why?

Should a little child use a tin, a silver or a china cup?

About Obedience and How It Is Obtained

What should a mother always add to the command "Don't do that"?

Why should the little child be trusted as much as possible?

Should a child be taught to obey as is an animal?

Should children be forced to obey commands based on personal wishes of their parents?

Why should children always feel that they are obeying a law, not an adult's whim?

How can unreasonable commands be avoided?

Under what general conditions of life is the question of obedience simplified?

Why is there need for clear thinking in issuing commands for children?

Under what conditions are "naughty" actions not punishable?

Why is it important that the child's natural impulse to see and to do things should not be suppressed?

How does the Casa dei Bambini inculcate absolutely quiet life for young children?

How treat a nervously exhausted child who is acting as if it were naughty?

THE SCHOOL OF REAL LIFE

WHAT A BOY MUST DO TO SUCCEED

EVERY boy looks eagerly forward to the time when he will be a man and will struggle for the prizes that are offered to men in the big world. Every man looks back to the time when he was a boy and feels that if he had a chance to try it over again, he could avoid many mistakes. In America every boy has great opportunities for success. With good health, and energy, and honesty, any boy may work his way to a successful career.

But the mistakes which a large number of boys make when they begin to work for themselves, the numerous blunders and failures among men, prove beyond question that real success in life's work is not easy, and is not to be had for the asking. It is not by plunging in recklessly and carelessly that men succeed, but by wise forethought, by faithful attention to business, by honesty and reliability.

In our time we are talking much of the vocational training of boys, that is, of a special training for business or trades and professions. The common school gives a general education, but does not prepare boys for special callings. Before trying one's chances of success in the big world it is well to take advice of older people who have had experience, who have suffered the hard bumps and discouragements, and can give boys good pointers as to how to conquer success.

That boy is most likely to win a place for himself in life who is willing to take advice, who will train himself thoroughly, who is not in too big a hurry to start out in the world, but first gets a good education, and if possible trains himself well for some special calling.

THE SCHOOL OF REAL LIFE

Life itself is a great school, and when we get out into the busy work of the world, we shall have plenty to learn. New problems and difficulties are coming up all the time. From the very start we must learn how to meet and master hard problems, to do disagreeable things, to stick steadily to what we undertake in spite of difficulties and discouragements. This big school of life is like all other schools—full of wise or unwise scholars. There are some who go through it day by day, week by week, year by year, as if life did not matter, waiting always for play-time, caring nothing for the things for which schools were made.

It is these students who keep down the proud reputation of the school. It is these, in the big school of the world, who are responsible for most of the misery and trouble of mankind.

Nothing can keep the boy back who means to go forward. The roads that lead to success in life are widening more and more. One may wander in a hundred fields and pick his prize. But no boy can get any farther than he aims. He must make up his mind where he is going and must remember that it is not only the way he goes that matters, but how far he goes that way; whether, when he has chosen the way, he quits himself like a man. He must remember that all useful work is honorable, and that the only dishonor in it is if it is badly done. And the task that is set before every man is, not to be this, or that, or the other—to mind a machine, to drive a plow, to write a book, to paint a picture; the great task set before a man is, so to prepare himself in youth that in carrying on his work in the world he shall do all things well.

THE QUALITIES THAT COIN SUCCESS

What, then, are the qualities that we need most on our way through the world? There are few things that all men agree about, but some things there are that every man knows to be true. And perhaps the first of these things is that to do anything worth doing in the world we must have a definite purpose. We must have an aim in life. We must make up our mind what we want to do, how we want to do it; and we must let nothing come in our way. We must think of time as what it really is—a treasure given to us for our safe keeping.

Time, it is said, is money. But time is much more than money, for time can do what all the money in the world can never do. Time can heal all sorrows and cure all ills, and time, if it is rightly used, gives opportunity too great to be realized by the young. Time spent in watching others play games, or in idling on the street is lost time. We do not want forever to be bent on serious things, and there is time for all of us to play; but nothing is so dangerous as amusement, and we had better never play at all than let play steal away our lives, and lead us to forget our aims.

And a boy must have ambition. He should not believe those who tell him there is anything wrong in the desire to get on well in the world. There is a right getting-on and a wrong getting-on, and when we say that we want to get on I hope we always mean, not merely that we want more money in our pocket, but that we want to know more as well as to have more; that we want more opportunities of well-doing and well-being. There are low ambitions and high ambitions. Let us see to it that we aim at a high purpose; that in Emerson's splendid words, we hitch our wagon to a star.

We must be resolute; we must have determination. It is no use having ideas unless we mean to carry them out. One other thing goes with determination, and that is concentration. One may have great energy, and may put it all into his work, but may use his strength in such a way that it simply fails. Everyone knows what a spendthrift is—the foolish man who throws away his money in stupid ways which serve no purpose instead of keeping it for something that is worth doing. Stick to the work—that is what is meant by concentration. It is wrong to try to do so many things that none of them can be done well. Time is wasted that is frittered away in little things that make no difference to anybody.

The boy who sticks to his work—that is the boy the world is waiting for. That is the boy who will paint the picture that everybody will go to see. That is the boy who will be manager of a big business. That is the boy that every mother wishes her son to be.

There are plenty of other boys; plenty of boys who will grow up to sell matches, or newspapers, and to do nothing particular for anybody, and worse than nothing for themselves. But the boy the world wants is the boy in earnest, the boy who is ambitious, the boy who is determined, the boy who will "stick to it."

THE USE OF DIFFICULTIES

It is often said in these days that life is made too easy, and that, because we have no longer to fight for our birthright as men fought in other days, we are not so strong and ready and daring as those who lived in harder times. There is just enough serious truth behind that to make it difficult to contradict, because life does, of course, become easier and happier as knowledge grows. If it did not, knowledge would not be worth having. The things that do not help us to live are not worth learning.

But it is not really true that life is becoming so easy that character has no chance to grow—which is what people mean when they look back and sigh for the good old times to come again. There never was such wicked nonsense as the talk about the good old times, and the man who sighs for them back again does not know what he is sighing for. There never were such good times as these in which we live. There never were such bad times as those that have gone. In the good old times little boys were forced up chimneys and down mines, and little girls were whipped to work in factories. That was one way of making them strong, but the pity was that most of them died without finding anything worth being strong for. Nothing can be more wicked than to wish for the dark, ignorant, cruel past to come back again.

Those who talk in this way imagine that character grows best in hard ground, and that therefore life must be made hard and cruel, and boys must be buffeted about, and perhaps beaten, or at any rate in some way brought to feel the cuts and blows of some outrageous fortune. The great untruth behind all this is the idea that cruelty is necessary to breed strength, that hardship is necessary to develop firmness, that we must make difficulties in order to develop the power of overcoming them.

It is true that overcoming difficulties is a fine way of growing strong, but it is true, also, that life is always difficult enough to develop the highest strength of character. In the great training grounds of the world the noblest human qualities can always grow, and life can never be so easy that one need fear he will lose his character, *if he wants to keep it.* The difficulties of life do not disappear; their nature changes—that is all. The boy who is going to make his mark in the world, however pleasant a place the world may be when he grows up, will find difficulties to overcome.

There will always be a world to conquer, and nearly always it lies about one, perhaps nearer than one's own door. The boy who gets over difficulties must make up his mind, at the very beginning of anything, what it is he wants to do, and having made up his mind, he must do it. He should let no difficulties turn him back from the way he should go. Only cowards count the cost of doing right, and shrink from it. The thing that is easy is there for anybody to do; it is the brave boy who will tread the difficult way, who will run a risk, and do the hard thing. There are people in the world who think it right to go through life taking all that life can give them and giving nothing in return; but they live their selfish lives and pass away and are forgotten. Out of their ranks no hero comes.

It is perfectly true that where there is a will to do a thing the way to do it can be found. A story is told of how Alexander the Great arrived one day at the city of Gordium, and found there a famous chariot fastened with cords tied into knots that no man could undo. And Alexander was told of the legend that whoever should untie the knots should rule the world. It was not like Alexander to waste his time untying knots, but he found a better way. He cut the knots asunder with his sword, and ever since the man who chooses the bold way out of a difficult situation has been said to cut the Gordian knot.

It is right to be cautious but it is wrong to be cautious even to timidity.

The world is not in want of men who will hold back. They are at the corner of every street; every town is full of them. It is the boy who will go forward that the world is waiting for—the Columbus, the Washington, the Livingstone of the future.

THE GLORY OF COURAGE

What the world needs is the courage that climbs over mountains or cuts them through, the boldness of a man who, knowing what is to be done, sees the difficulties and conquers them. We would not be living in a free country, the land we live in would still be overrun with barbarism, if men had chosen the easy way. One has only to think for a moment of the things which every boy knows to see the spirit that conquers the world. Such a spirit was that of Columbus at the court of Spain, fighting against prejudice and ignorance and blindness until his courage moved a queen to pledge her jewels for the expedition that was to discover America. It is the spirit that General Grant displayed in his military campaigns, that remarkable persistence and steadiness of purpose, which never faltered, and wrought out his great victories. David Livingstone shows this spirit, poring over his books till midnight, getting up at six o'clock in the morning, and working in the factory till eight at night, going to school from eight to ten, then poring over his Latin grammar again as long as his eyes would keep open, and then sleeping till six o'clock brought back another day. He worked half a year in the factory, and spent his wages in the next half at the university. He never met, either then or as a man, any difficulty that he allowed to stand in his way. His stubborn will conquered the hot fever-laden climate of Africa.

At a time when all America was talking of Mr. Roosevelt, an American paper said jokingly, "Just stop to think that Theodore Roosevelt is only one nine-hundred-and-forty-thousandth of one per cent of the population of the United States." But it was the genius of Mr. Roosevelt that he would not let America think that. The man who means to have his own way may count only one in the census paper, but he may count a million ones in history.

All things come to him whose spirit will not die. The men who have transformed the world—what sort of lives were theirs? They read their books by candle-light and lived in garrets, they toiled long hours down in mines and rarely saw the sun, they prayed in vain for one word of sympathy; for the bold man with the new idea had all the world against him until these modern times.

It is hard to believe the difficulties that were put in the way of men who looked into the future years ago, and laid the foundation of comfortable lives for those who live now, and of prosperity for nations.

Robert Fulton, the man who made steam navigation a success, was scoffed and jeered at on every hand; not one word of encouragement, not one bright hope, not one warm wish crossed his path, he said.

George Stephenson was denounced as an impostor when he began to make his railways; and one of the saddest things in the history of any nation is the story of the bitter struggle to save the little children of England from slavery. They were whipped to work like dogs, until so many died that they were buried in secret to hide the awful truth.

Times have changed, but still it is true that the path of the good man through this world is strewn with thorns. Men have so much to do, and so little time, and so many things to bother them, that it is hard to interest them, and harder still to get their help; and so we are discouraged and downhearted, and noble causes lag for want of friends.

It is always so. But the boy should arm himself in the days in which he is putting on his strength against the disappointments that must come into his life. They will come, whatever happens, and at times it will seem to him as if the sun had gone out, and as if nothing matters and nobody cares. But he will remember that, however dark the clouds are, the sun breaks through again. He must not let despair seize hold of him because the task is hard and there seems to be no way out. He can sustain himself by the proud thought that he is in the line of heroes. Behind him stand Captain Scott and David Livingstone and George Washington and Abraham Lincoln and Francis Drake and Joan of Arc, and he will not shame these mighty names by turning back.

The thing that is in the way is the great test, the touchstone of an enterprise. Two boys meet a difficulty, and it is like the instrument at the mint which touches every sovereign, throwing out the bad and keeping the good. One boy turns back, but the other is true as steel. The fear of danger, the sight of a mountain, the touch of risk, the wondering whether he will really manage it, are new life to him. He goes on with new zest and resolution, and almost before he sees the difficulty it has gone. Like melting snow difficulties go when a brave heart comes along.

Especially must he be on his guard against the difficulties that do not exist.

Some of your hurts you have cured,
And the sharpest you still have survived;
But what torments of grief you endured
From evils which never arrived!

Half the people in this world spend half their lives in wondering how they will get over a stile that they will never reach. One of the wisest things ever written in a copy book is, "Do not meet troubles half way." Time is too precious to spend in imagining difficulties; they will come soon enough.

Even wise men are wrong sometimes. Perhaps you have read how, in the early days of railways, men spent their time in trying to get over the difficulty of making a smooth wheel ride over a smooth rail. The wheels would skid on the smooth lines, it was said, and for years men saw no way out. Then at last, somebody tried a smooth wheel on a smooth rail, and found that the difficulty did not exist.

Only a great daring, an inflexible purpose, an unquenchable spirit of perseverance, can rouse the world from its indifference and drive away defeat. In little things and great, in the trials of our own lives and in the public things we fight for, we must dare to do right, whatever the consequences may be.

He either fears his fate too much,
Or his deserts are small,
Who dares not put it to the touch,
To gain or lose it all.

There are nobler things than boldness, there are baser things than fear. But there is nothing sadder than the fear of doing right; there is nothing nobler than the fear of doing wrong. Let that be the only fear. Let the soul be pure, let the heart be brave. Be strong and of good courage. He that overcometh shall inherit all things.

WHAT A GIRL MUST DO TO SUCCEED

YOU are sure to be wondering, as you stand at the gates of Life and look out upon the world, what destiny the hidden years can hold for you. As surely as the leaves fall, in obedience to the Hand that guides the heavens, so surely your unfolding life is dawning, and will rise to noonday, and will sink into the gentle sleep of night, to the bidding of the universal law that none can break.

But because your life is part of the great world you will not believe that therefore it is fixed for you, so that you have no choice. You are free to do as you will. You are free to use your life or to waste it. In the great scheme which even now is building up a perfect world, your life must have its place. But you are not a spectator looking on at the world. You are an actor, taking part in it, and the great play of Life will fail so far as you fail in your part.

And you are wondering, no doubt, what part you will play—whether you will go out into the world to do great things, or whether you will be content to be of the multitude which moves in quiet paths, doing good without ceasing, making life a blessing, but winning neither wealth nor fame. And you must resolve for yourself the question that every girl must ask herself—whether you will seek first the natural place of woman in the home, or whether, in some wider sphere, you will seek to carve out an independent place. It is the most important thing you can decide, and nothing can be more difficult than to advise you.

USE OF NATURAL GIFTS

But of one thing it is easy and right to advise you. You can do no wrong in putting your natural gifts to any natural use. You can do no wrong in fitting yourself for any office you can fill with profit to yourself and usefulness to others. You can do no wrong in choosing any path that leads you to your destiny with dignity and honor. But you may do yourself great wrong, and may betray the cause that every woman holds in trust, if you cut yourself off, knowingly and purposely, from the noblest work that daughters and wives and mothers are called upon to do.

You are growing up in an age when too many people are willing to sully the fair fame of a woman. Of all the sad things that happen in these days, nothing is sadder than the things that make us forget for a moment the gentleness and graciousness of womanhood. It is a beautiful vision that comes to us as we think of our mothers, and of their mothers, and of mothers all down the ages of time; but how easy it is sometimes to forget the things that make the thought of women so comforting and uplifting! You will have nothing to do with the vulgar manners you will see about you, with girls who would be men, forgetting how much greater than men they could really be. When you find yourself in the company of a girl who smokes, keep your modesty and leave her; she is not going your way. In such small things begin the end of modest girlhood. The manners of men are not for girls to put on as they put on hats and gloves.

The men for whose esteem a girl should crave have no esteem to spare for girls who ape their habits without thinking, who break through the fine reserve that is a girl's best safeguard, who mix with men and come down to meet them, when men instead should rise to their higher level. All through the world, and all through life, the *something better* in a woman has been the world's great blessing, and nothing that the world can give will be worth having if you lose this priceless thing.

Whatever way you choose through life, you will guard the noblest thing your mother gave you—the charm of being made in her own image. You will cherish the thought that the love for a mother is the strongest influence in the world, and you will do nothing to wreck the place a mother holds in the deathless affection of mankind.

THE GREAT POWER YOU WILL HAVE TO STIR MEN TO GLORIOUS THINGS

You will not mind the scoffing of those who are careless in small things; you will be ready to give up lawful pleasures rather than run the risk of losing the fair name which is worth more to you than rubies. The knight's armor, in the days of chivalry, was buckled on by his lady, and the beautiful meaning of that should still be true in these days. It was the gracious way in which a lady sent out her knight to fight with double strength.

This is the great power for woman still, so long as she keeps her hold upon her knight. The things that are unseen are hers, the influences that reach deep down in the heart of life, and never wholly fail. How often it is that the man who seems so powerful, who seems to do as he likes and to conquer wherever he goes, is really swayed by a great love behind him, and nearly always the love of a woman.

A BLOW THAT YOU MAY STRIKE AT A WRONG VIEW OF LIFE

You may be rightly proud of the gifts which enable you to win your own way in the working world, and there is no reason anywhere why you should not place yourself by the side of men in any sphere in which you can hold your own. So long as your work fits you, *and does not unfit you*, for your natural destiny, it can be nothing but a blessing. It can bring you nothing but happiness to be conscious of a power to face the world whatever happens, and in the years when you are building up your life you may wisely seek the discipline and training of some useful service. The useless have no rights, and we must be useful. Even though your lot be cast in pleasant places, so that you may not need to earn your living, it will do you no harm to do some useful work. The real wages for good work are not made at the mint.

The girl who wins a place by her own efforts has strengthened herself in any task she undertakes. She has struck the hardest blow she can at the silly notion that woman must be a sort of on-looker at the world.

THE GREAT TEMPTATIONS THAT WILL COME TO YOU TO WASTE YOUR DAYS

Thousands of lives have been saved from ruin by a definite work in life; thousands have been wrecked by the want of it; and nothing will more likely prepare you for the coming years than a definite piece of wisely chosen work, whether for wages or for love of doing it.

"Our time," said Sir Walter Scott, "is like our money. When we change a dollar, the dimes escape as things of small account; when we break a day by idleness in the morning, the rest of the hours lose their importance in our eyes." Idle hours are temptations, but idle years are worse, and it is not surprising that the end of nothing-in-particular-to-do for years should be a consuming love of pleasure. And then often in its train comes the sad waste and vanity of it all—the love of vain things.

THE EMPTY VANITY THAT FLAUNTS ITSELF BEFORE THE WORLD

We need not object to anything beautiful, but the vanity of riches is not the love of beauty; and the things that are worn because they are ticketed at a high price in a shop, and so advertise the splendid incomes of those who wear them, are not things to admire. You will learn to love things that are really beautiful, to prize things that are really valuable, and you will scorn the empty show which flaunts itself so much before the world and has nothing lovely or noble, or really worthy behind it.

Life is not simple, and it is not easy always to know what to do; but it will help you, now that you are wondering which way you will go, if you make up your mind to go the simple way.

THE GIRL WHO LOVES HER HOME

You have learned that happy homes are not made with hands. The foundations may be deeply set, the great walls may rise high and the windows may look out upon a noble scene, the room may be rich beyond avarice and beautiful beyond compare, and there may be nothing wanting to please the stranger's eye; but the seat of happiness is not in these things. If one invisible thing is absent no visible splendor can atone for it; nothing that we can touch or taste or hear or see can help us if this thing is missing. Every day, for want of it, homes are wrecked and lives are broken.

You will guess that this invisible foundation of a happy home is the love of those who live in it. Love and happiness run together. There can be no transgression of that law. Whatever else is false this much is true, that hearts divided against themselves can never make a home. And so you will resolve that your home shall be built upon this firm foundation.

And so you will feel that your home is the shrine of sacred things, a field in which the seed you sow may grow into a precious harvest.

You will think of your home as your own little corner of the world, where you are queen and you will set your influence as on a rock. You will love your friends outside your home, you will cherish goodwill to your neighbors, but within the walls of your own kingdom you will give yourself unselfishly and toil unceasingly for those who are banded together as one, heart of your heart, mind of your mind, life of your life, traveling beside you through sunlight and shadow, through ill and good report.

THE LITTLE WORLD IN WHICH YOU WILL MAKE YOUR OWN LAWS AND KEEP THEM

We are in the world and of the world, and we must take our place and play our part. If we could rule the world for just one week, we have thought sometimes, how happy a place we would make it! Well, our homes are our own worlds, in which we make our laws and administer them, in which we lay down our rules of life and declare our relation to our neighbors and mankind. Your home will be the place where you find rest, but your rest will bring you new strength, and you will spend it for the good of all.

THE QUALITIES THAT ARE CALLED FOR IN MANAGING A HOME

Nothing in the world, perhaps, is more difficult than the wise management of a house. Most of us are too ready to forget, in enjoying the great freedom of home, that a home is like a machine, and must have method and discipline if it is to have peace. It is a wonderful thing, considering the millions of opposite interests in the world, and all the selfishness and indifference, that the world agrees so well; and it is not surprising that the management of a home, with perhaps six people of six different types, with tastes that can vary in perhaps a hundred things, with conflicting desires in food, and pleasure, and friendships, and with varying needs in other ways, should call for the very greatest care and judgment.

It is not an easy task to control the home-life of a family, fitting all these desires into a general plan, giving freedom and happiness to each and contentment to all, and it is harder still if some break the rules. You will not be ashamed to acknowledge that your place is in the kitchen as well as in the drawing-room. The proper management of a kitchen is one of the greatest services a woman can render to the world.

If we think of the lives of the great multitude of working people, it is easy to see how bad food, bad cooking, bad housekeeping, can spoil them utterly, and we have yet to measure the effect of these things in driving men out of their homes and into public-houses. If it is true that the public-house, with its horrible associations, all its germs of disease, has taken the place of home in the lives of masses of men, who shall say how many of these men turn to such places in search of the comfort missing from their homes?

THE GREAT NUMBER OF THINGS WE CAN DO WITHOUT IN THE WORLD

You will learn very soon, in building up your home, that simplicity of life is the golden key to happiness. It is one of the sad consequences of the progress of the world that civilization brings with it a great increase in what we call our needs, though they are really only our desires. Crave for the things that will make you happy, but do not create unnecessary wants. It is astonishing to think of the number of things we gather into our houses that we do not really need.

THE ENDURING JOY OF HOME THAT COMES FROM SIMPLICITY

Make up your mind that the simpler a home is, the more enduring is the joy of it; the more natural our environment is, the more natural we ourselves shall be. Let us set our faces, in our homes and out of them, against what is artificial and conventional. It is art and good sense to have few things in a home, instead of many, and to have these of the best; and it is good to have them natural, instead of artificial, with some idea in them that helps us, or inspires us, or brings us pleasure. It is good to have real things instead of imitations; it is good to have a few of the very best pictures rather than a whole gallery of meaningless daubs; and it is good to have about us the books that we love. It is good, in a word, to live in a house that seems to be a part of nature herself, helping us in our natural life, and deepening within us the love of true and noble and beautiful things.

THE WISE WORDS OF SOLOMON ON THE WISE WIFE IN THE HOUSE

You will spend these early years, while your own home is still afar off, in fitting yourself for it. You will not be afraid of the great task to which you set your hand. You will know the high mission that you undertake, you will rejoice in the high privilege of building up a home, and you will build it in the spirit of King Solomon when he wrote: "As the sun when it ariseth in the high heaven, so is the beauty of a good wife in the ordering of her house."

THE GIRL IN SEARCH OF PLEASURE

The first duty of a girl, a wise man said once, is to be happy. Unless we can be happy, life is hardly worth while.

That perhaps may seem to you a strange thing because you know of so many lives that are a great blessing to the world, though they may seem to you about as sad as anything can be. And it is perfectly true that noble lives may be full of sacrifice and sorrow; perhaps it is even true that sacrifice and sorrow make thousands of lives noble and useful which but for these things might be lived in vain. But all through the years that are opening out before you you will find one thing becoming clearer and clearer in your mind; you will find that the pleasure-seekers are not always glad, and the sorrow-bearers are not always sad. You will find that there is a secret of happiness which neither money, nor social advantage, nor education can buy, and which neither poverty, nor sickness, nor other ills of this world can utterly destroy.

And so we learn to understand that there are ways to happiness which perhaps we have not guessed. Happiness is much more than a mere passing sense of pleasure, and we should seek to build up the happiness of our lives on an enduring foundation. No mere round of social pleasures, no mere pleasing things that last for an hour and are gone, can give us that. Pastime has its proper place, and it is true that all work and no play makes Jill a dull girl, but the ordinary amusements of life are not the true source of happiness.

One of your temptations will be to rely upon these things when you should seek enjoyment in other ways, and there is perhaps no greater enemy of girlhood than the ceaseless round of empty pleasures that assail the girl who comes face to face with life on her own account. It is so easy to do this and that, to go here and there, that you are sure to be tempted to give yourself too much to the side of life which is meant only as recreation.

Doubtless you will discover, long before you have yielded to this temptation, that the best way to be happy is to plan your life so that pleasures come into it naturally instead of being outside it, as it were. Nothing could be more unwise than the sort of life some people live, divided into two compartments. One compartment is for work, which we should rather call drudgery, for it brings them no joy and is done against their will; the other compartment is for pleasure, which we should rather call pastime, for it is merely relief from their duller life, and is simply a stupid way of passing time which their dull minds do not know how to use. It is true that some of us must do the duller kinds of work if the world is to go on, and no doubt stitching all day long, or making boxes, or adding up figures, or typing letters are not as interesting as painting pictures, or writing books, or managing businesses; but most of us have no real excuse for not being interested in our work, and it is a sad thing to turn it into such a drudgery that we must seek relief from it at any cost.

THE DUTIES AND PLEASURES THAT WILL FIT IN WITH ONE ANOTHER

You will not fall between these two extremes—the burden of work which bores you and the reaction of amusement which gives you no real compensation; you will make your whole life so interesting that you will not need to pay other people to amuse you in order to escape from it. You will look a long way ahead of you. You will have a definite purpose in your life, and you will see, as far as you can, that its duties and pleasures fit in one with the other, so that they lead and follow each other naturally instead of being like opposite things.

THE COMPANY WE KEEP WHEN WE ENJOY OUR PLEASURES

You would not think of taking certain people home; you would shrink from telling your mother that you had been with them at dinner, or walking with them in the street, or sitting with them by the fire, or talking freely with them. We need not think ourselves better than other people, and it is no hollow hypocrisy, and no sort of priggishness, that turns us from the company of those whose way of life is not ours. The natural pride of life, the dignity of girlhood, will cause you to shrink from evil things not less if they come in the form of men and women than if they come as serpents, and it will help us if we realize that, whenever we go to see men and women of bad character on the stage, appealing to their audiences by the very atmosphere with which they have become associated, we are *in the company of these people* as if we had invited them to our homes.

You will be on the side of pure pleasures always, but you will hate the vulgarities which pretend to be entertainments, and you will rather die than countenance with your presence some of the shameful scenes that take place openly in theaters and music-halls.

YOU WILL SEE THAT YOUR PLEASURES ARE WORTHY OF YOUR HEART AND MIND

When anything impure is done, or said, or sung in your presence, in public or in private, you will be faced with a problem that you must instantly decide: you will have to stay and lose your dignity, or to go and keep it, and you will go. It shall not be said of you that you stained the fair fame of the people's pleasures by patronizing a hideous thing. You will be sure a play is sweet before you go to see it, just as you will be sure that a man is honorable before you consent to know him.

And, especially you will take care, in choosing your public pleasures, that they are worthy of you in another sense; you will refuse to enjoy yourself at the cost of another's pain. You will be ashamed to think that another human being should imperil his life, or her life, to please you, and you will refuse to be pleased by the sight of other people risking death to earn a living. You will be shocked to think that there should be any pain or fear or sorrow caused to others in order that you might enjoy a pleasant hour, and you will ask yourself what a mother's anxiety must be while her boy, or her girl, or her breadwinner, hangs in danger of death on an iron bar high up in the air; or how little children must live in dread of something happening to their father, who stands in danger every night that you might watch and be excited by his peril. You will love life too much to think lightly of endangering it for others, and you will turn in pity, if not in disgust, from so-called pleasures which involve grave peril to life and limb.

THE TERRIBLE PRICE YOU WILL NEVER PAY FOR THE THINGS YOU WEAR

You will dress for neatness and not for show, and you will not think your hat, or your coat, so important that for their sake you can throw aside your charity and gentleness and love of justice.

You will not think it worth while to starve a family of fellow-creatures in order that you may wear a pretty hat. You would blush for shame if you were asked to wear a thing that had been stolen; how much more then you will blush if you should find yourself wearing one day a beautiful thing bought by torture and cruelty and the wanton shedding of blood! It is right that we should remember the terrible words uttered not long ago by a professor who had been investigating the circumstances under which aigrette feathers are obtained, and who declared that *every girl who wears an aigrette has the murderer's brand upon her brow.* It is a terrible saying, but it is true.

It is enough to say here that an aigrette's feather can be obtained only by the most terrible acts of cruelty that men can inflict upon birds, and that every plume of an aigrette, or a gull, or a bird of paradise, is obtained by the murder of a mother bird at the time when she is bringing up her little ones, so that she hovers round the nest and is easily caught.

THE GIRL WHO THINKS AND FEELS

You are thinking and feeling about a thousand things in these years in which you are laying the foundations of a world. What a solemn thing that is to say, and yet it is true that every one of us, in the days of our youth, is building a world as certainly as he who builds up stone on stone and crowns them with towers and domes. We come into a world that is open to receive us; for a few short years we live in the world as we find it; but soon, perhaps almost sooner than we know, we are making our own world, carving our own way, shaping our own thoughts, controlling our own destinies.

We are like travelers sent out on a journey, set in a path well marked and beaten down by the feet of friends who have gone before us. For a little way the path is clear and narrow, and friends protect and guide us as we go: we follow where they lead. But soon the way grows wide, and our friends are scattered; and the paths lead here and there, and cross and cross; and the signposts are so confusing, and in such strange languages, that we only half perceive their meaning; and we wander on and on, through unknown ways to unknown lands. No longer is the path marked out for us; we make it as we go, and we go whither we will.

Life is like that. We reach it through a narrow, guarded way, which leads into infinite space. We come into it with minds like a garden not yet planted—with soil half prepared, perhaps, so that it may have a tendency towards flowers instead of weeds, or towards weeds instead of flowers; but with the actual seeds unsown, so that we may make the garden almost what we will. For a little while the flowers come up about us and we have almost nothing to do with them; but soon the seeds are offered us by a thousand hands, bearing a thousand kinds of fruit, and we can take them or reject them as we will. What shall we take, and what shall we reject?

That is what will make our lives, building them up or pulling them down. The things we put into our pockets may be as nothing, though they be made of gold; but the things we put into our minds are all the world to us, though they fall from the skies, or rise from the valleys, or pour out upon us from the hills, and cost us nothing. *We are what we think.* We are as old as we feel, as rich or as poor as our imagination. We are as strong as our faith or as weak as our fears. It is these things that make up life for us: it is your mind that makes your world, and your mind is *what you make it.*

You have often heard people say, no doubt, that if they could make their own world they would be perfectly happy, and perhaps you have thought so too. Well, the boundaries of your kingdom are rising up around you, and you are forming them. Even now, while life is so pleasant and the years bring no burden for you to carry, you are laying for yourself the foundations of a world in which you will live, I hope, to a serene old age. Upon the thoughts you admit into your mind now, more than upon anything else, will rest the fortunes of your future years, and you can hand on to your future no more precious inheritance than a mind well filled, well balanced, and well controlled.

WE MUST BE BRAVE ENOUGH TO RESTRAIN OUR FEELINGS

It is not easy to restrain the natural feelings of pity that come to us when we see or hear sad things, and it will be a sad day for the world when sorrow and pain cease to stir our feelings. But it would be worse for us all if, in our pity, we shut our eyes and hearts and minds to other feelings. We must be strong enough to bear the sight of pain for healing's sake, or where would doctors and nurses come from? We must be stern enough to punish wrong-doing, or what would become of peaceful people? It is right that we should regret the need of causing pain, but it is wrong that we should shun the painful duties that we owe to ourselves and to others. We must learn to look wisely upon all sides of life, and not give way to the feelings that belong to only one side of things.

WHY WE MUST GIVE OUR REASON FULL CONTROL OF OUR EMOTIONS

And so we see that we must give our reason full control of our emotions. We must think long, long thoughts, and not only for the moment and the hour. We must not let momentary feelings, so lightly roused, govern the acts of our lives. We must not let one emotion seize hold of us, and control us and dominate our lives until it possesses us completely. We must not let our love of dogs, for example, blind us to the fact that sometimes, at the cost of a little pain to one of these brave animals, we may save the lives of children. We must not let any emotion so utterly possess us that we are carried away by it.

Without this balance, this careful adjustment of the scales of reason and emotion, our lives must lose much of their happiness for ourselves and much of their usefulness to others.

THE MISTAKE THAT WE MUST GUARD AGAINST IN GIVING OUR SYMPATHIES

All through our lives we shall be forming our opinions, fixing our attitude to this or that great movement, resolving which side we will take in a hundred questions. From all sides the appeal to our sympathy will come and in the stress of life, in the midst of all its clashing interests, it will not be easy to decide. Often it will seem that two ways are right, when only one can be taken, and often the way that seems right will mean pain to those we love, or suffering to ourselves that we could avoid by pursuing another way. And sometimes it will seem as if to find the truth is quite impossible.

THE STILL SMALL VOICE WITHIN THAT WILL NEVER BETRAY US

When these things come we shall do what seems to us right; we shall listen to the still small voice within us which never yet has led any one of us astray. We shall remember, not merely the things that crowd upon our minds at the moment, but the way in which the acts of our lives are wrought into a chain that never ends, but links the human race from age to age. In all things we must consider the far-off end, the ultimate purpose of Life.

You will have your share of the fears and worries that come to us all, and you will bear them bravely. But you will be wise, and you will not suffer your feelings to mislead you. You will open your heart to sorrow, you will open your mind to knowledge, and you will live in a world of thought and feeling which not all the armies of this world could destroy.

PRACTICAL ARITHMETIC AND CALCULATIONS

THE FUNDAMENTAL PROCESSES

Addition

Addition is a short way of uniting two or more numbers into one number.

The numbers to be added are called *Addends.*

The result of adding is called the *Sum.*

The sign of addition (+) is the erect cross, which is read "plus" or "and."

The sign of equality is =, or two short horizontal lines placed one above the other. It is read "equals."

Only numbers of the same kind can be added. We can add 4 cows and 9 cows; the sum is 13 cows; but we cannot add 6 books and 4 slates, as the sum would be neither books nor slates.

A number of some particular kind, as 5 balls, 6 horses, is called a *Concrete Number.*

A number used without reference to any particular thing, as 8, is an *Abstract Number.*

Any two or more abstract numbers can be united into one sum because they do not refer to any particular objects.

ORAL EXERCISES

Count by 2's to 100; by 3's to 99; by 4's to 100; by 5's to 100; by 6's to 96; by 7's to 98; by 8's to 96; by 9's to 99.

Beginning with 1, count by 2's to 99.

Beginning with 1, count by 3's to 100; beginning with 1, count by 4's to 97; beginning with 1 count by 5's, by 6's, by 7's, by 8's and by 9's.

ADDITION DRILL

Note.—This table contains all of the primary combinations in addition. It should be learned for speed and reviewed frequently. Every child should learn to be speedy with this table.

	A	B	C	D	E	F	G	H	I	J
1.	1	1	2	1	3	3	4	4	3	1
	1	2	2	3	2	3	1	2	4	5
2.	5	4	1	5	4	2	7	2	1	8
	2	4	6	3	5	6	1	7	8	2
3.	3	5	9	7	4	2	4	5	6	7
	6	5	1	3	6	9	8	7	5	4
4.	5	8	6	9	7	3	8	7	8	9
	9	3	6	6	8	9	9	7	8	2
5.	5	9	8	6	6	8	7	9	9	8
	8	9	6	9	7	5	9	4	6	7

Use this table as a drill in every possible way, up and down and to the right and to the left. Use a watch to encourage speed.

Method or Rule for Addition.—In order to add numbers conveniently, write the numbers so that units shall be under units, tens under tens, hundreds under hundreds, and so on. Add each column separately, beginning at the right. If the sum of any column is greater than 9, set down only the right-hand figure of the sum and add the other figure to the next column to the left.

EXERCISES

Add—

1.	2.	3.	4.	5.	6.
7832	9132	7911	4668	7848	2314
7386	8617	5687	4578	8337	8430
7510	2731	1234	7433	8664	9999
1832	3056	7638	6340	7931	6327
1647	7690	1967	3257	5419	6327
9975	9537	4350	1861	3228	6730

Note.—The above problems should be used to attain speed and accuracy. Make this a game in which the pupils are contesting to win. Have them start at a given signal.

WRITTEN PROBLEMS

1. A cottage was planned to cost $1000. The foundation and brick work cost $428.80, lumber $370.15, carpentering $264.87, painting and plastering $253.25, hardware $38.90, tinwork $13.78. What did the house actually cost?

2. A farm which cost $6275 was equipped as follows: House $1588.77, teams, $850, a driving horse $175, cattle $275, hogs $127, implements and tools $677. What is the total value of the farm and its equipment?

3. A family of two persons spends for rent $130, food, $210, clothing $80, fuel $30, light $6, insurance $24, replenishing $10, carfare $5, literature $5, charity $10, and saves $20. What is the income?

4. Find the cost of raising an acre of corn if the rent is $3.03, fertilizer $1.86, plowing, etc., $1.62, planting $1.42, cultivating $1.80, harvesting $3, and other expenses $1.76.

Subtraction is the process of finding the difference between two numbers. The larger of the two numbers is called the *Minuend.* The number which is subtracted is called the *Subtrahend.*

The result of the subtraction is the *Difference* or *Remainder.*

SUBTRACTION DRILL

Note.—The teacher using a watch should place a limit of so many seconds, say thirty, and see who can go farthest with this table in this time. Use every device you can to encourage this rapid work and do it every day until the pupil is proficient.

Subtract—

8	6	7	8	7	5	6	7	9	8
5	2	3	6	2	2	4	4	7	3
6	7	8	9	6	9	8	9	9	9
3	5	4	2	2	4	2	3	5	6
10	11	10	12	11	10	12	10	11	12
7	3	8	5	4	6	6	5	7	9
13	11	13	12	13	14	11	12	11	12
4	5	7	8	9	9	6	7	9	4
14	15	16	11	15	13	14	12	13	11
8	9	8	8	6	6	7	3	5	2
13	15	14	16	16	14	15	18	17	17
8	7	6	9	7	5	8	9	9	8

MAKING CHANGE

In making change we add to the amount of the sale enough money to equal the amount given in payment.

Example.—A customer buys goods amounting to $3.45 and gives a five-dollar bill in payment. Count out the change.

Amount of sale:	Change:
$3.45	$0.05
	.50
	1.00
	$1.55

$1.55 Amount of change.

$5.00 Amount given in payment.

Merchant says: "Three-forty-five, three-fifty, four dollars, five dollars."

The merchant desiring to use the least number of pieces of money would hand the customer his package, a nickel, a halfdollar, and a dollar, and say, "three-forty-five, three-fifty, four, five dollars."

The customer should always count his change as the merchant makes it.

ORAL PROBLEMS IN MAKING CHANGE

	Amount of Sale	Money Payment	Change
1.	$ 0.30	a half dollar	how much? what pieces?
2.	.65	one dollar	how much? what pieces?
3	1.02	a dollar and a quarter	how much? what pieces?
4.	1.35	two dollars	how much? what pieces?
5.	1.55	five-dollar bill	how much? what pieces?
6.	2.20	two two-dollar bills	how much? what pieces?
7.	3.65	a five-dollar bill	how much? what pieces?
8.	6.85	a ten-dollar bill	how much? what pieces?
9.	11.65	a twenty-dollar bill	how much? what pieces?

WRITTEN EXERCISES

1. From 896,192 subtract 425,327.

```
        5  11  8  12
      ______________
 8  9  6    1  9  2
 4  2  5    3  2  7
 ___________________
 4  7  0    8  6  5
```

You cannot take 7 units from 2 units. Take 1 ten from 9 tens; this with the 2 units makes 12 units. This leaves 5 units.

Eight tens remain in the Minuend. Taking 2 from 8 leaves 6.

In a similar manner, taking 3 from 11 leaves 8, taking 5 from 5 leaves 0, taking 2 from 9 leaves 7 and taking 4 from 8 leaves 4.

2. From 6,000,600 subtract 172,316.

```
 6  9  9  10  5  9  10
 _____________________
 6  0  0   0  6  0   0
    1  7   2  3  1   6
 _____________________
 5  8  2   8  2  8   4
```

When the Minuend contains zeros think of each zero as 9 except the right-hand one in each group which is thought of as 10. Note that 1 of the 6 hundreds in the Minuend makes the 9 tens and the 10 units. Also, 1 of the 5 millions makes the 9 hundreds, the 9 tens, and the 10 units of the thousands 8 period.

CHECKING SUBTRACTION

The accuracy of the work is checked by adding the Difference to the Subtrahend. The sum of these two numbers should be the same as the Minuend.

Subtract—

1.	2.	3.	4.	5.	6.
760	571	4705	21,504	34,576	78,765
369	296	2482	18,396	22,688	56,899

WRITTEN PROBLEMS

1. From London to Bombay by the Cape of Good Hope is 11,220 miles; by way of the Suez Canal it is 6332 miles. How many miles does the Suez Canal save in going by water from London to Bombay?

2. The distance from New York to San Francisco by way of Cape Horn is 13,135 miles; by way of Panama it is 5262 miles. Find the distance saved by the Panama Canal.

3. From New York to Melbourne by way of Cape Horn is 12,852 miles; by way of Panama Canal it is 10,392 miles. How much does the Panama Canal save between New York and Melbourne?

Multiplication

Multiplication is a short way of adding a set of equal numbers. Thus: $4 \times 3 = 12$, is the short way of writing 3 plus 3 plus 3 plus 3 equals 12; and $7 \times 4 = 28$, is the short way of writing 4 plus 4 plus 4 plus 4 plus 4 plus 4 plus 4 equals 28.

The number to be multiplied is called the *Multiplicand;* the number by which we multiply is called the *Multiplier;* and the result of the process is called the *Product.* The Multiplier and Multiplicand are also sometimes called the Factors of the Product.

THE MULTIPLICATION TABLE

NOTE.—It is absolutely necessary for every pupil to know this table thoroughly in order to make any progress at all in Arithmetic. Use the watch in timing each pupil. A pupil should be able to give any one table forward and backward in from thirty to forty seconds. No child who cannot do this should be allowed to think that he has mastered this table:

CHART I

Have children count by 1's; 2's; 4's and 3's.

Teach that multiplication is a short method of adding.

◆ Signifies new numbers found in other tables of Charts I and II.

\+ Signifies old numbers having been studied in other tables of Charts I and II.

Let the children discover in the new table how many numbers they have studied in other tables.

	1 × 1 =			1
◆	2 × 1 =			2
◆	3 × 1 =			3
◆	4 × 1 =			4
◆	5 × 1 =			5
	6 × 1 =			6
	7 × 1 =			7
	8 × 1 =			8
◆	9 × 1 =			9
◆	10 × 1 =		1	0
◆	11 × 1 =		1	1
	12 × 1 =		1	2

+	1 × 2 =			2
	2 × 2 =			4
◆	3 × 2 =			6
◆	4 × 2 =			8
◆	5 × 2 =		1	0
	6 × 2 =		1	2
	7 × 2 =		1	4
	8 × 2 =		1	6
◆	9 × 2 =		1	8
◆	10 × 2 =		2	0
◆	11 × 2 =		2	2
	12 × 2 =		2	4

+	1 × 4 =			4
+	2 × 4 =			8
	3 × 4 =		1	2
	4 × 4 =		1	6
◆	5 × 4 =		2	0
	6 × 4 =		2	4
	7 × 4 =		2	8
	8 × 4 =		3	2
◆	9 × 4 =		3	6
◆	10 × 4 =		4	0
◆	11 × 4 =		4	4
	12 × 4 =		4	8

+	1 × 3 =			3
+	2 × 3 =			6
	3 × 3 =			9
+	4 × 3 =		1	2
◆	5 × 3 =		1	5
	6 × 3 =		1	8
	7 × 3 =		2	1
	8 × 3 =		2	4
◆	9 × 3 =		2	7
◆	10 × 3 =		3	0
◆	11 × 3 =		3	3
	12 × 3 =		3	6

CHART A

Drill the 1's, 2's, 4's, and 3's separately as a closing review for each of the tables studied.

Develop the fact of the reversibility of numbers as 1 × 2 =, 2 × 1 =, etc., except the square of numbers as 1 × 1 =, 2 × 2 =, etc. Develop or omit drills as circumstances require.

Study the 5's and 6's with Chart II.

The numbers in black on this chart and on Chart C indicate the numbers in the 6's; 7's, 8's and 12's not studied in the other eight tables.

These numbers are tabulated for study on Chart II. If the numbers are properly reviewed in couplets, the children will show an intelligent appreciation of the fact that they have only ten combinations to study in these four tables.

1 × 1 =	2 × 1 =	3 × 1 =	4 × 1 =	5 × 1 =	6 × 1 =
1 × 2 =	1 × 2 =	1 × 3 =	1 × 4 =	1 × 5 =	1 × 6 =
2 × 1 =	2 × 2 =	3 × 2 =	4 × 2 =	5 × 2 =	6 × 2 =
1 × 3 =	2 × 3 =	2 × 3 =	2 × 4 =	2 × 5 =	2 × 6 =
3 × 1 =	3 × 2 =	3 × 3 =	4 × 3 =	5 × 3 =	6 × 3 =
1 × 4 =	2 × 4 =	3 × 4 =	3 × 4 =	3 × 5 =	3 × 6 =
4 × 1 =	4 × 2 =	4 × 3 =	4 × 4 =	5 × 4 =	6 × 4 =
1 × 5 =	2 × 5 =	3 × 5 =	4 × 5 =	4 × 5 =	4 × 6 =
5 × 1 =	5 × 2 =	5 × 3 =	5 × 4 =	5 × 5 =	6 × 5 =
1 × 6 =	2 × 6 =	3 × 6 =	4 × 6 =	5 × 6 =	5 × 6 =
6 × 1 =	6 × 2 =	6 × 3 =	6 × 4 =	6 × 5 =	**6 × 6 =**
1 × 7 =	2 × 7 =	3 × 7 =	4 × 7 =	5 × 7 =	**6 × 7 =**
7 × 1 =	7 × 2 =	7 × 3 =	7 × 4 =	7 × 5 =	7 × 6 =
1 × 8 =	2 × 8 =	3 × 8 =	4 × 8 =	5 × 8 =	**6 × 8 =**
8 × 1 =	8 × 2 =	8 × 3 =	8 × 4 =	8 × 5 =	8 × 6 =
1 × 9 =	2 × 9 =	3 × 9 =	4 × 9 =	5 × 9 =	6 × 9 =
9 × 1 =	9 × 2 =	9 × 3 =	9 × 4 =	9 × 5 =	9 × 6 =
1 × 10 =	2 × 10 =	3 × 10 =	4 × 10 =	5 × 10 =	6 × 10 =
10 × 1 =	10 × 2 =	10 × 3 =	10 × 4 =	10 × 5 =	10 × 6 =
1 × 11 =	2 × 11 =	3 × 11 =	4 × 11 =	5 × 11 =	6 × 11 =
11 × 1 =	11 × 2 =	11 × 3 =	11 × 4 =	11 × 5 =	11 × 6 =
1 × 12 =	2 × 12 =	3 × 12 =	4 × 12 =	5 × 12 =	**6 × 12 =**
12 × 1 =	12 × 2 =	12 × 3 =	12 × 4 =	12 × 5 =	12 × 6 =

CHART B

DRILLS FOR BLACKBOARD OR PAPER

Suggestions for blackboard or speed drills to be used at the discretion of the teacher. This may be developed throughout all the tables. The children should know each combination independently and instantaneously.

× 1		÷ 1	
5			11
3			4
8			7
11			10
4			1
12			6
7			9
1			2
9			5
6			8
2			12
10			3

× 2		÷ 2	
7			22
12			10
3			18
5			4
9			12
1			20
8			8
6			24
10			16
4			2
11			6
2			14

× 4		÷ 4	
12			40
9			8
1			12
6			32
10			20
7			4
3			44
11			36
8			28
2			16
5			24
4			48

× 3		÷ 3	
9			24
1			3
6			9
10			18
8			30
5			12
11			6
7			36
2			15
12			27
4			21
3			33

CHART II

Thoroughly develop the idea of units, tens and hundreds columns. Again master each table separately and review as suggested by drill charts before beginning a new table.

1st. Suggest that the 10 is made of a cipher in its units number and a 1 in its tens number. Also that the units number in the answer is a cipher; and that the 10's or 10's and 100's numbers are the same as the numbers we multiply by 10.

Teach that multiplying by 10 is the same as multiplying by 1 and adding an 0 to the units column.

This idea may be developed into rapid drills of multiplying by 10's; 100's; 1000's; etc., by adding 0's.

The 2's, 4's, and 3's can be reviewed by multiplying by 20, 40, and 30; or by 200, 400, and 300, etc., by adding 0's.

2nd. Note that the 11 is composed of 2 ones; and that in the answer, both the units and tens columns contain the same numbers, as 11, 22, etc. The black line separates numbers not belonging to the rule (10 × 11) = (11 × 10); , ∴ only two combinations remain to be studied.

+	1 × 10 =		1	0
+	2 × 10 =		2	0
+	3 × 10 =		3	0
+	4 × 10 =		4	0
◆	5 × 10 =		5	0
	6 × 10 =		6	0
	7 × 10 =		7	0
	8 × 10 =		8	0
◆	9 × 10 =		9	0
	10 × 10 =	1	0	0
◆	11 × 10 =	1	1	0
	12 × 10 =	1	2	0

+	1 × 11 =		1	1
+	2 × 11 =		2	2
+	3 × 11 =		3	3
+	4 × 11 =		4	4
◆	5 × 11 =		5	5
	6 × 11 =		6	6
	7 × 11 =		7	7
	8 × 11 =		8	8
◆	9 × 11 =		9	9
+	10 × 11 =	1	1	0
	11 × 11 =	1	2	1
	12 × 11 =	1	3	2

+	2 × 5 =		1	0
+	4 × 5 =		2	0
	6 × 5 =		3	0
	8 × 5 =		4	0
+	10 × 5 =		5	0
	12 × 5 =		6	0
+	1 × 5 =			5
+	3 × 5 =		1	5
	5 × 5 =		2	5
	7 × 5 =		3	5
◆	9 × 5 =		4	5
+	11 × 5 =		5	5

+	1 × 9 =			9
+	2 × 9 =		1	8
+	3 × 9 =		2	7
+	4 × 9 =		3	6
+	5 × 9 =		4	5
	6 × 9 =		5	4
	7 × 9 =		6	3
	8 × 9 =		7	2
	9 × 9 =		8	1
+	10 × 9 =		9	0
+	11 × 9 =		9	9
	12 × 9 =	1	0	8

	6 × 6 =		3	6
	7 × 6 =		4	2
	8 × 6 =		4	8
	12 × 6 =		7	2
	7 × 7 =		4	9

	8 × 7 =		5	6
	12 × 7 =		8	4
	8 × 8 =		6	4
	12 × 8 =		9	6
	12 × 12 =	1	4	4

Keep the facts observed in mind during drills.

3d. First multiply 5 by even numbers, then by odd numbers. Note that 5 is one-half of 10 and that the answers are just one-half as much as if multiplied by 10.

Note that even numbers multiplied by 5 have 0 in their unit column; but (2 × 5) = only one-half (2 × 10), etc. Odd numbers multiplied by 5 have 5 in their units column. Drill on (3 × 5) = (1 × 10 + 5); (5 × 5) = (2 × 10 + 5); etc.

4th. Let the children suggest the simple points they see in the 9's. Have them observe 9 is one less than 10; and their answer in the 10's column is one less than the number they have multiplied by 9.

The sum of the ten's and units columns is 9. The black line denotes the exceptions. (11 × 9) = (9 × 11); ∴ there is only one combination to study. Drill and review.

5th. For the 10 numbers of the 6's, 7's, 8's and 12's tables, follow previous directions.

7 × 1 =	8 × 1 =	9 × 1 =	10 × 1 =	11 × 1 =	12 × 1 =
1 × 7 =	1 × 8 =	1 × 9 =	1 × 10 =	1 × 11 =	1 × 12 =
7 × 2 =	8 × 2 =	9 × 2 =	10 × 2 =	11 × 2 =	12 × 2 =
2 × 7 =	2 × 8 =	2 × 9 =	2 × 10 =	2 × 11 =	2 × 12 =
7 × 3 =	8 × 3 =	9 × 3 =	10 × 3 =	11 × 3 =	12 × 3 =
3 × 7 =	3 × 8 =	3 × 9 =	3 × 10 =	3 × 11 =	3 × 12 =
7 × 4 =	8 × 4 =	9 × 4 =	10 × 4 =	11 × 4 =	12 × 4 =
4 × 7 =	4 × 8 =	4 × 9 =	4 × 10 =	4 × 11 =	4 × 12 =
7 × 5 =	8 × 5 =	9 × 5 =	10 × 5 =	11 × 5 =	12 × 5 =
5 × 7 =	5 × 8 =	5 × 9 =	5 × 10 =	5 × 11 =	5 × 12 =
7 × 6 =	8 × 6 =	9 × 6 =	10 × 6 =	11 × 6 =	12 × 6 =
6 × 7 =	6 × 8 =	6 × 9 =	6 × 10 =	6 × 11 =	6 × 12 =
7 × 7 =	8 × 7 =	9 × 7 =	10 × 7 =	11 × 7 =	12 × 7 =
7 × 8 =	7 × 8 =	7 × 9 =	7 × 10 =	7 × 11 =	7 × 12 =
8 × 7 =	**8 × 8 =**	9 × 8 =	10 × 8 =	11 × 8 =	12 × 8 =
7 × 9 =	8 × 9 =	8 × 9 =	8 × 10 =	8 × 11 =	8 × 12 =
9 × 7 =	9 × 8 =	9 × 9 =	10 × 9 =	11 × 9 =	12 × 9 =
7 × 10 =	8 × 10 =	9 × 10 =	9 × 10 =	9 × 11 =	9 × 12 =
10 × 7 =	10 × 8 =	10 × 9 =	10 × 10 =	11 × 10 =	12 × 10 =
7 × 11 =	8 × 11 =	9 × 11 =	10 × 11 =	10 × 11 =	10 × 12 =
11 × 7 =	11 × 8 =	11 × 9 =	11 × 10 =	11 × 11 =	12 × 11 =
7 × 12 =	**8 × 12 =**	9 × 12 =	10 × 12 =	11 × 12 =	11 × 12 =
12 × 7 =	12 × 8 =	12 × 9 =	12 × 10 =	12 × 11 =	12 × 12 =

CHART C

Follow previous directions. This chart may also be combined with Chart A; and studied across the pages instead of down the columns.

Blackboard drills as suggested by Chart B may be continued effectively.

CHART III

This review chart is so arranged, that all the answers are in order according to size from 1 to 144. Also all combinations having the same answers are classed together. It is useful for busy work, or rapid drills.

1 × 1 =	1 ×12 =	4 × 6 =	11 × 4 =	6 ×12 =
1 × 2 =	12 × 1 =	6 × 4 =	5 × 9 =	12 × 6 =
2 × 1 =	2 × 6 =	5 × 5 =	9 × 5 =	7 ×11 =
1 × 3 =	6 × 2 =	3 × 9 =	4 ×12 =	11 × 7 =
3 × 1 =	3 × 4 =	9 × 3 =	12 × 4 =	8 ×10 =
1 × 4 =	4 × 3 =	4 × 7 =	6 × 8 =	10 × 8 =
4 × 1 =	2 × 7 =	7 × 4 =	8 × 6 =	9 × 9 =
2 × 2 =	7 × 2 =	3 ×10 =	7 × 7 =	7 ×12 =
1 × 5 =	3 × 5 =	10 × 3 =	5 ×10 =	12 × 7 =
5 × 1 =	5 × 3 =	5 × 6 =	10 × 5 =	8 ×11 =
1 × 6 =	2 × 8 =	6 × 5 =	6 × 9 =	11 × 8 =
6 × 1 =	8 × 2 =	4 × 8 =	9 × 6 =	9 ×10 =
2 × 3 =	4 × 4 =	8 × 4 =	5 ×11 =	10 × 9 =
3 × 2 =	2 × 9 =	3 ×11 =	11 × 5 =	8 ×12 =
1 × 7 =	9 × 2 =	11 × 3 =	7 × 8 =	12 × 8 =
7 × 1 =	3 × 6 =	5 × 7 =	8 × 7 =	9 ×11 =
1 × 8 =	6 × 3 =	7 × 5 =	6 ×10 =	11 × 9 =
8 × 1 =	2 ×10 =	3 ×12 =	10 × 6 =	10 ×10 =
2 × 4 =	10 × 2 =	12 × 3 =	5 ×12 =	9 ×12 =
4 × 2 =	4 × 5 =	4 × 9 =	12 × 5 =	12 × 9 =
1 × 9 =	5 × 4 =	9 × 4 =	7 × 9 =	10 ×11 =
9 × 1 =	3 × 7 =	6 × 6 =	9 × 7 =	11 ×10 =
3 × 3 =	7 × 3 =	4 ×10 =	8 × 8 =	10 ×12 =
1 ×10 =	2 ×11 =	10 × 4 =	6 ×11 =	12 ×10 =
10 × 1 =	11 × 2 =	5 × 8 =	11 × 6 =	11 ×11 =
2 × 5 =	2 ×12 =	8 × 5 =	7 ×10 =	11 ×12 =
5 × 2 =	12 × 2 =	6 × 7 =	10 × 7 =	12 ×11 =
1 ×11 =	3 × 8 =	7 × 6 =	8 × 9 =	12 ×12 =
11 × 1 =	8 × 3 =	4 ×11 =	9 × 8 =	

CHART IV

The six tables containing the most difficult numbers are arranged vertically instead of horizontally, so that the child may become accustomed to the difference in the position of numbers.

	3 × 1	1 3	3 2	2 3	3 3	3 4	4 3	3 5	5 3	3 6	6 3
3 7	7 3	3 8	8 3	3 9	9 3	3 10	10 3	3 11	11 3	3 12	12 3
	4 1	1 4	4 2	2 4	4 3	3 4	4 4	4 5	5 4	4 6	6 4
4 7	7 4	4 8	8 4	4 9	9 4	4 10	10 4	4 11	11 4	4 12	12 4
	6 1	1 6	6 2	2 6	6 3	3 6	6 4	4 6	6 5	5 6	6 6
6 7	7 6	6 8	8 6	6 9	9 6	6 10	10 6	6 11	11 6	6 12	12 6
	7 1	1 7	7 2	2 7	7 3	3 7	7 4	4 7	7 5	5 7	7 6
6 7	7 7	7 8	8 7	7 9	9 7	7 10	10 7	7 11	11 7	7 12	12 7
	8 1	1 8	8 2	2 8	8 3	3 8	8 4	4 8	8 5	5 8	8 6
6 8	8 7	7 8	8 8	8 9	9 8	8 10	10 8	8 11	11 8	8 12	12 8
	12 1	1 12	12 2	2 12	12 3	3 12	12 4	4 12	12 5	5 12	12 6
6 12	12 7	7 12	12 8	8 12	12 9	9 12	12 10	10 12	12 11	11 12	12 12

CHART D

1

It is suggested that as the children study the tables and review, they should be required to count by the number by which they have learned to multiply, and that in final review, they should be able to write them as suggested here, and cross out all the numbers that occur more than once.

2

This could be used for busy work drills; or, the teacher could select products, and require the children to give all the combinations that make them. It is also interesting to add some number to the product, as 37 instead of 36. The children will then give

$$(6 \times 6 + 1); \quad \left.\begin{matrix} 4 \times 9 \\ 9 \times 4 \end{matrix}\right\} + 1; \quad \left.\begin{matrix} 12 \times 3 \\ 3 \times 12 \end{matrix}\right\} + 1.$$

1

1	~~2~~	~~3~~	~~4~~	~~5~~	~~6~~	~~7~~	~~8~~	~~9~~	~~10~~	~~11~~	~~12~~
2	~~4~~	~~6~~	~~8~~	~~10~~	~~12~~	~~14~~	~~16~~	~~18~~	~~20~~	~~22~~	~~24~~
3	~~6~~	~~9~~	~~12~~	~~15~~	~~18~~	~~21~~	~~24~~	~~27~~	~~30~~	~~33~~	~~36~~
4	~~8~~	~~12~~	~~16~~	~~20~~	~~24~~	~~28~~	~~32~~	~~36~~	~~40~~	~~44~~	~~48~~
5	~~10~~	15	~~20~~	25	~~30~~	~~35~~	~~40~~	~~45~~	~~50~~	~~55~~	~~60~~
6	~~12~~	~~18~~	~~24~~	~~30~~	~~36~~	~~42~~	~~48~~	~~54~~	~~60~~	~~66~~	~~72~~
7	14	21	28	35	42	49	~~56~~	~~63~~	~~70~~	~~77~~	~~84~~
8	16	24	32	~~40~~	~~48~~	56	64	~~72~~	~~80~~	~~88~~	~~96~~
9	18	27	~~36~~	45	54	63	~~72~~	81	~~90~~	~~99~~	~~108~~
10	20	30	40	50	~~60~~	70	80	90	100	~~110~~	~~120~~
11	22	33	44	55	66	77	88	99	110	121	~~132~~
12	24	36	48	60	72	84	96	108	120	132	144

2

1's	10's	20's	30's	40's	50's	60's	70's	80's	90's	100's
1	10	20	30	40	50	60	70	80	90	100
2	11	21	32	42	54	63	72	81	96	108
3	12	22	33	44	55	64	77	84	99	110
4	14	24	35	45	56	66		88		120
5	15	25	36	48						121
6	16	27		49						132
7	18	28								144
8										
9										

METHOD OF MULTIPLICATION

1. Multiply 46 by 10.

Adding a zero to the right of 46 changes the 6 to 60 and the 40 to 400; hence it multiplies the number by 10.

2. Multiply 426 by 300.

Long Method:	Short Method:
426	426
300	300
000	127800
000	
1278	
127800	

3. How many 0's would you annex to the right of your product if your multiplier were 20? 200? 80? 1000? 40,000?

Tell the products of the following at sight.

4.	10×800	9.	20×32
5.	10×775	10.	70×50
6.	10×185	11.	100×20
7.	10×128	12.	400×50
8.	10×381	13.	1000× 7

14. Multiply 8207 by 345.

15. Multiply 8217 by 305.

Multiplicand	8207
Multiplier	345
First Partial Product	41035
Second Partial Product	32828
Third Partial Product	14621
Entire Product	2832415

15. Multiply 8217 by 305.

Multiplicand	8217
Multiplier	305
First Partial Product	41085
Second Partial Product	24651
Entire Product	2506185

PROBLEMS

1. A grocer has two grades of butter, one of which sells for 40 cents a pound and the other for 32 cents a pound. How much will a family save in a year (52 weeks) by using the cheaper grade if they use three pounds a week?

2. When round steak is 22 cents a pound, and sirloin is 27 cents a pound, how much will a family that uses 64 pounds a month save by using round steak?

3. Suppose you could buy two kinds of flour, one at 75 cents a sack and the other at 88 cents a sack, and you use 18 sacks a year, how much more does the expensive flour cost you a year?

Division

ORAL EXERCISES

1. Count by 6's from 36 to 0. How many 6's in 36. Count by 9's from 36 to 0.

From the above you will see that there are four 9's in 36, also that there are nine 4's in 36. Thus if we take 9 as a factor 4 times we have the product 36. In division we have given the product and one of the two factors to find the other factor.

Dividing the product by either factor gives the other factor: Thus: 36÷9=4; 36÷4=9.

In this case 36 is called the *Dividend;* while the factor used to divide by we call the *Divisor.* The result obtained by dividing which is the other factor, we call the *Quotient.*

SHORT DIVISION

When the divisor is not greater than 12 a process called *Short Division* is usually used.

1. Divide 852 by 3.

Solution:

3)852
254

EXPLANATION.—3 is contained in 8 (hundreds) 20 (hundred) times with a remainder of 2.

Write 2 in the hundreds place of the quotient. The remainder, 2 hundreds plus 5 tens, equals 25 tens.

25 tens divided by 3 equals 8 tens, with a remainder of 1.

Write 8 tens in the quotient in tens place. The 1 ten remainder plus 2 units equals 12 units.

12 units divided by 3 equals 4 units.

2.	856÷4	8.	1078÷7
3.	1624÷6	9.	792÷6
4.	1272÷6	10.	9136÷4
5.	1054÷9	11.	7468÷7
6.	1728÷8	12.	11,656÷9
7.	772 ÷5	13.	16,860÷6

WRITTEN PROBLEMS

160 Y　　　58006/6000

1. 600)96000　　2. 6000)348096
3. Divide 480 by 10; by 20; by 30.4.
4. Divide 7200 by 40; by 400; by 900.
5. Divide 9600 by 60; by 600; by 800.
6. Divide 112000 by 700; by 800; by 7000.
7. Divide 108000 by 900; by 1200; by 9000.

NOTE.—A problem in division is checked or proved by multiplying the divisor by the quotient and adding the remainder, if there be one, to the product; the result should be the dividend.

LONG DIVISION

1. Divide 8745 by 37.

$236\frac{13}{37}$

Divisor: 37)8745 Dividend
74
134
111
235
222
13

EXPLANATION.—37 is contained in 87 (hundreds) 2 (hundreds) times with 13 (hundreds) as remainder. The figure 2 is set down in the hundreds place of the quotient.

13 hundreds plus four tens equals 134 tens. 37 is contained in 134 (tens) 3 (tens) times, with a remainder of 23 tens. Place 3 in the quotient in tens place. 23 tens plus 5 units equals 235 units. 37 is contained in 235 units 6 times with a remainder of 13 units.

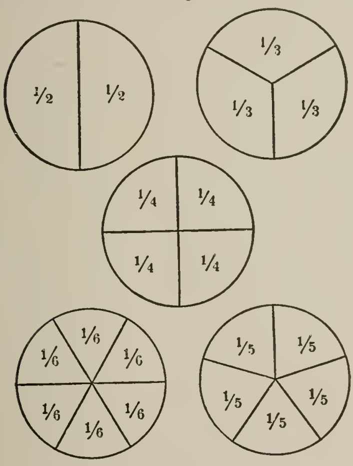
2. Divide 42832 by 184.
3. Divide 48210 by 85.
4. Divide 27152 by 67.
5. Divide 377289 by 927.

FRACTIONS

A *Fraction* is one or more of the equal parts into which a unit is divided: as one-third, three-fourths.

A Fraction is expressed by one figure written over another figure with a line between: $\frac{2}{3}$, $\frac{3}{5}$.

A Fraction may also be regarded as an indicated division; that is, $\frac{3}{4}$ is the same as $3 \div 4$.



The *Denominator* of a Fraction is the number below the line. It shows into how many equal parts the given unit is divided. Thus in $\frac{3}{4}$ the Denominator is 4.

The *Numerator* of a Fraction is the number which shows how many equal parts are taken. It is written above the line; thus in $\frac{3}{5}$ the Numerator is 3.

The Numerator and Denominator of a Fraction are called its *terms*.

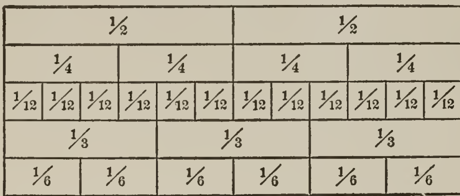
A Fraction whose Numerator is less than its Denominator is called a *Proper Fraction;* as $\frac{5}{6}$, $\frac{9}{10}$.

A Fraction whose Numerator is equal to or greater than its Denominator is an *Improper Fraction:* as $\frac{4}{4}$; $\frac{9}{7}$.

A number composed of a Whole Number and a Fraction is called a *Mixed Number;* as $4\frac{3}{5}$. It is read "four and three-fifths."

REDUCTION OF FRACTIONS

The process of changing the form of a Fraction without changing its value is called *Reduction:* $\frac{1}{2}=\frac{2}{4}=\frac{8}{16}$.



A Fraction is reduced to lower terms when its terms are made smaller numbers; that is, $\frac{9}{12}$ is reduced to $\frac{3}{4}$, which are its lowest terms.

Multiplying or dividing both terms of a fraction by the same number does not change its value.

$\frac{2}{3}\times\frac{4}{4}=\frac{8}{12}$. $\frac{8}{12}\div\frac{4}{4}=\frac{2}{3}$.

Supply the missing Term:

1. $1=\frac{\ }{4}$; $1=\frac{\ }{8}$; $1=\frac{\ }{12}$; $\frac{3}{3}=\frac{\ }{6}$; $\frac{3}{3}=\frac{\ }{12}$.
2. $\frac{1}{2}=\frac{\ }{6}$; $\frac{1}{3}=\frac{\ }{12}$; $\frac{2}{3}=\frac{\ }{9}$; $\frac{2}{3}=\frac{\ }{12}$; $\frac{2}{3}=\frac{\ }{18}$.
3. $\frac{1}{6}=\frac{\ }{12}$; $\frac{4}{6}=\frac{\ }{12}$; $\frac{6}{6}=\frac{\ }{12}$; $\frac{2}{6}=\frac{\ }{3}$; $\frac{4}{6}=\frac{\ }{3}$.
4. $\frac{2}{12}=\frac{\ }{6}$; $\frac{4}{12}=\frac{\ }{3}$; $\frac{4}{12}=\frac{\ }{6}$; $\frac{8}{12}=\frac{\ }{6}$.

Solve without pencil, filling in blank numerator:

1. $\frac{1}{2}=\frac{\ }{4}$; $\frac{1}{3}=\frac{\ }{12}$; $\frac{2}{3}=\frac{\ }{18}$; $\frac{2}{3}=\frac{\ }{24}$; $\frac{2}{3}=\frac{\ }{27}$.
2. $\frac{1}{3}=\frac{\ }{6}$; $\frac{1}{4}=\frac{\ }{12}$; $\frac{3}{4}=\frac{\ }{16}$; $\frac{1}{8}=\frac{\ }{24}$; $\frac{3}{8}=\frac{\ }{24}$.
3. $\frac{1}{6}=\frac{\ }{18}$; $\frac{1}{5}=\frac{\ }{15}$; $\frac{2}{5}=\frac{\ }{15}$; $\frac{2}{5}=\frac{\ }{25}$; $\frac{3}{5}=\frac{\ }{30}$.
4. $\frac{1}{6}=\frac{\ }{24}$; $\frac{5}{6}=\frac{\ }{24}$; $\frac{5}{6}=\frac{\ }{30}$; $\frac{7}{8}=\frac{\ }{48}$; $\frac{5}{9}=\frac{\ }{45}$.
5. $\frac{5}{12}=\frac{\ }{120}$; $\frac{7}{12}=\frac{\ }{84}$; $\frac{5}{12}=\frac{\ }{96}$; $\frac{11}{12}=\frac{\ }{120}$; $\frac{11}{12}=\frac{\ }{144}$.

Reduce to Lowest Terms.—A Fraction is in its lowest terms when both its terms contain no common divisor. Thus $\frac{2}{3}$ is in its lowest terms since 2 and 3 have no common divisor.

A fraction is reduced to lower terms by dividing both of its terms by the same number; thus $\frac{10}{15}$ is reduced to $\frac{2}{3}$ by dividing both terms by 5.

$$\frac{10\div5}{15\div5}=\frac{2}{3}$$

Reduce to lowest terms without a pencil:

	a	b	c	d	e	f	g
1.	$\frac{4}{8}$	$\frac{6}{10}$	$\frac{8}{12}$	$\frac{12}{24}$	$\frac{15}{30}$	$\frac{18}{20}$	$\frac{16}{24}$
2.	$\frac{10}{15}$	$\frac{10}{25}$	$\frac{15}{40}$	$\frac{20}{35}$	$\frac{14}{35}$	$\frac{18}{27}$	$\frac{18}{36}$
3.	$\frac{6}{12}$	$\frac{9}{18}$	$\frac{12}{24}$	$\frac{18}{24}$	$\frac{16}{36}$	$\frac{18}{32}$	$\frac{24}{36}$
4.	$\frac{12}{20}$	$\frac{18}{30}$	$\frac{12}{32}$	$\frac{20}{24}$	$\frac{22}{42}$	$\frac{24}{80}$	$\frac{22}{44}$
5.	$\frac{15}{40}$	$\frac{35}{70}$	$\frac{25}{80}$	$\frac{40}{90}$	$\frac{35}{90}$	$\frac{50}{100}$	$\frac{80}{100}$

Reduce to lowest terms with pencil:

1. $\frac{128}{320}$

Solution. $\frac{128}{320}=\frac{32}{80}=\frac{4}{10}=\frac{2}{5}$ Ans.

2. $\frac{90}{105}$; $\frac{96}{176}$; $\frac{228}{250}$; $\frac{124}{144}$; $\frac{108}{240}$.
3. $\frac{138}{288}$; $\frac{216}{480}$; $\frac{250}{750}$; $\frac{450}{900}$; $\frac{1250}{1000}$.
4. $\frac{225}{300}$; $\frac{750}{1250}$; $\frac{750}{1000}$; $\frac{250}{750}$; $\frac{450}{1000}$.

Reducing Whole or Mixed Numbers to Improper Fractions.—Reduce $2\frac{1}{3}$ to thirds.
Solution: $2\times\frac{3}{3}=\frac{6}{3}+\frac{1}{3}=\frac{7}{3}$

Rule.—Multiply the whole number by the denominator and add the numerator for a numerator. Under it write the given denominator.

Solve without pencil:

1. $5\frac{3}{4}=\frac{}{4}$; $3\frac{1}{3}=\frac{}{3}$; $5\frac{2}{3}=\frac{}{3}$; $6\frac{2}{3}=\frac{}{3}$.
2. $4=\frac{}{4}$; $5\frac{3}{5}=\frac{}{5}$; $5\frac{5}{6}=\frac{}{6}$; $4\frac{1}{8}=\frac{}{8}$.
3. $6=\frac{}{2}$; $6\frac{1}{3}=\frac{}{3}$; $6\frac{2}{5}=\frac{}{5}$; $8\frac{1}{3}=\frac{}{3}$.

Solve with pencil:

4. Reduce $33\frac{2}{3}$ to thirds.
   Solution. $33\times3=\frac{101}{3}$ Ans.
5. $62\frac{1}{4}$; $133\frac{1}{3}$; $166\frac{2}{3}$; $137\frac{1}{2}$; $187\frac{1}{2}$.
6. $270\frac{3}{5}$ feet; $310\frac{5}{6}$; \$$73\frac{1}{10}$; $16\frac{5}{12}$ years; $111\frac{19}{20}$ acres.

Reducing an Improper Fraction to a whole or mixed number; show by making and dividing circles that $\frac{5}{2}=2\frac{1}{2}$; $\frac{7}{3}=2\frac{1}{3}$; $\frac{9}{4}=2\frac{1}{4}$.

Solve without pencil, reducing to whole or mixed numbers:

1. $\frac{7}{2}$; $\frac{7}{3}$; $\frac{9}{3}$; $\frac{11}{2}$; $\frac{12}{4}$; $\frac{15}{4}$; $\frac{21}{5}$.
2. $\frac{15}{3}$; $\frac{16}{4}$; $\frac{25}{4}$; $\frac{15}{5}$; $\frac{18}{5}$; $\frac{27}{5}$; $\frac{28}{6}$.

Reduce to whole or mixed numbers with pencil:

3. Reduce $\frac{545}{17}$ to a whole or mixed number:

Solution. 545 $32\frac{1}{17}$

```
17)545
   51
   --
    35
    34
    --
     1
```

4. $\frac{55}{12}$ $\frac{254}{8}$ $\frac{501}{9}$ $\frac{132}{11}$ $\frac{675}{12}$ $\frac{100}{12}$ $\frac{200}{15}$ $\frac{1000}{6}$
5. $7\frac{2}{3}$ feet; $\frac{59}{8}$ mi.; \$$\frac{293}{10}$; $\frac{124}{5}$ days; $\frac{163}{7}$ weeks; \$$\frac{756}{11}$; \$$\frac{877}{15}$; \$$\frac{508}{35}$.

Reducing Fractions to the Least Common Denominator.—Those Fractions which have the same denominator are called *Similar Fractions.* The Fractions, $\frac{1}{6}$, $\frac{3}{6}$ and $\frac{5}{6}$, are Similar Fractions. In order to add or subtract Fractions conveniently, we must reduce them to similar fractions.

1. Reduce $\frac{1}{3}$, $\frac{7}{8}$, $\frac{5}{12}$ to similar fractions.

Solution:

3)3, 8, 12 $\frac{1}{3}=\frac{}{24}$; $\frac{1}{3}=\frac{8}{24}$.

4)1 8 4 $\frac{7}{8}=\frac{}{24}$; $\frac{7}{8}=\frac{21}{24}$.

1 2 1 $\frac{5}{12}=\frac{}{24}$; $\frac{5}{12}=\frac{10}{24}$

$3\times4\times2=24$, the Common Denominator.

2. Reduce $\frac{2}{5}$, $\frac{5}{7}$, $\frac{7}{35}$ to Similar Fractions.

Solution:

5)5, 7, 35 $\frac{2}{5}=\frac{}{35}$; $\frac{2}{5}=\frac{14}{35}$.

7)1, 7, 7 $\frac{5}{7}=\frac{}{35}$; $\frac{5}{7}=\frac{25}{35}$.

1, 1, 1

$5\times7=35$, the Least Common Denominator.

Reduce to Least Common Denominator.

3. $\frac{5}{7}$, $\frac{9}{14}$, $\frac{8}{21}$.
4. $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{8}$.
5. $\frac{4}{9}$, $\frac{5}{27}$, $\frac{4}{36}$, $\frac{11}{54}$.
6. $\frac{17}{18}$, $\frac{23}{24}$, $\frac{15}{32}$.
7. $\frac{5}{8}$, $\frac{5}{24}$, $\frac{7}{72}$, $\frac{6}{144}$.
8. $\frac{4}{9}$, $\frac{5}{27}$, $\frac{4}{36}$, $\frac{12}{54}$.
9. $\frac{3}{10}$, $\frac{4}{25}$, $\frac{4}{30}$, $\frac{7}{50}$.
10. $\frac{7}{8}$, $\frac{3}{16}$, $\frac{5}{32}$, $\frac{7}{64}$.

ADDITION OF FRACTIONS

To add Fractions, reduce them to similar fractions, that is, to fractions having the same denominator, then add the numerators and place the sum over the common denominator.

1. Add $\frac{2}{3}$, $\frac{5}{6}$, $\frac{7}{8}$.

Solution: $\frac{2}{3}+\frac{5}{6}+\frac{7}{8}=$
$\frac{16}{24}+\frac{20}{24}+\frac{21}{24}=\frac{57}{24}=\frac{19}{8}=2\frac{3}{8}$. Ans.

Find the sum of:

2. $\frac{1}{4}$, $\frac{1}{6}$, $\frac{9}{18}$.
3. $\frac{5}{32}$, $\frac{19}{24}$, $\frac{5}{48}$.
4. $\frac{1}{8}$, $\frac{3}{32}$, $\frac{1}{84}$.
5. $\frac{1}{16}$, $\frac{17}{20}$, $\frac{29}{36}$.
6. $\frac{9}{8}$, $\frac{5}{24}$, $\frac{17}{18}$.
7. $\frac{4}{9}$, $\frac{5}{12}$, $\frac{11}{27}$, $\frac{23}{36}$.
8. $\frac{7}{8}$, $\frac{9}{10}$, $\frac{2}{3}$, $\frac{5}{6}$, $\frac{11}{15}$.

TO ADD MIXED NUMBERS

First add the Whole Numbers; then add the Fractions; then add the two results obtained.

Add:

1. $5\frac{1}{4}$, $7\frac{1}{8}$, and $6\frac{3}{4}$.

Process:

$5\frac{1}{4}$ $\frac{1}{4}+\frac{1}{8}+\frac{3}{4}=$

$7\frac{1}{8}$

$6\frac{3}{4}$ $\frac{2}{8}+\frac{1}{8}+\frac{6}{8}+\frac{9}{8}=1\frac{1}{8}$.

18

$1\frac{1}{8}$

$19\frac{1}{8}$ Ans.

2. $2\frac{3}{8}$, $5\frac{2}{3}$, and $9\frac{1}{4}$.
3. $10\frac{3}{5}$, $12\frac{1}{3}$, and $7\frac{8}{15}$.
4. $13\frac{5}{6}$, $5\frac{5}{12}$, and $21\frac{6}{48}$.
5. $24\frac{3}{4}$, $32\frac{7}{8}$, and $21\frac{3}{24}$.

TO SUBTRACT FRACTIONS

Reduce to Similar Fractions and subtract the less numerator from the greater for a new numerator to be written over the common denominator.

1. Subtract $\frac{5}{8}$ from $\frac{11}{12}$.

Process:

$\frac{11}{12}-\frac{5}{8}=\frac{22}{24}-\frac{15}{24}=\frac{7}{24}$. Ans.

Find the value of:

2. $\frac{5}{6}-\frac{2}{3}$	7. $\frac{205}{96}-\frac{75}{64}$
3. $\frac{7}{12}-\frac{5}{9}$	8. $\frac{14}{15}-\frac{6}{25}$
4. $\frac{17}{24}-\frac{11}{18}$	9. $\frac{47}{120}-\frac{23}{75}$
5. $\frac{6}{7}-\frac{1}{3}$	10. $\frac{5}{18}-\frac{4}{81}$
6. $\frac{29}{30}-\frac{7}{25}$	11. $\frac{61}{64}-\frac{55}{72}$

12. $\frac{19}{100}-\frac{17}{1000}$

MULTIPLICATION OF FRACTIONS

To multiply a Fraction by a Whole Number, multiply the numerator of the Fraction by the Whole Number and write result over the given denominator, then simplify. Use cancellation.

1. Multiply $\frac{9}{12}$ by 15.

SOLUTION: $\frac{9}{12}\times 15=\frac{135}{12}=11\frac{3}{12}$ or $11\frac{1}{4}$. Ans.

Multiply:

2. $\frac{5}{12}$ by 6.	5. $\frac{4}{15}$ by 5.
3. $\frac{17}{24}$ by 4.	6. $\frac{3}{40}$ by 8.
4. $\frac{7}{16}$ by 4.	7. $\frac{7}{12}$ by 6.

To multiply a Fraction by a Fraction multiply the numerators together for a new numerator and the denominators together for a new denominator. Use cancellation whenever possible.

1. Multiply $\frac{4}{7}$ by $\frac{14}{5}$.

SOLUTION: $\frac{4}{7}\times\frac{14}{5}=\frac{8}{5}=1\frac{3}{5}$. Ans. Find the value of:

2. $\frac{5}{6}\times\frac{9}{10}$	4. $\frac{25}{27}\times\frac{36}{35}$
3. $\frac{6}{7}\times\frac{21}{22}$	5. $\frac{3}{5}\times\frac{4}{9}\times\frac{5}{16}$

DIVISION OF FRACTIONS

Reduce Whole Numbers to the form of Fractions, by writing 1 as their denominators. Reduce Mixed Numbers to Improper Fractions; then invert the divisor and multiply.

1. Divide 30 by $\frac{5}{12}$.

SOLUTION: $\frac{30}{1}\div\frac{5}{12}=$
$\frac{30}{1}\times\frac{12}{5}=72$. Ans.

Find the value of:

2. $\frac{3}{8}\div\frac{3}{4}$	6. $\frac{12}{21}\div\frac{6}{7}$
3. $16\div\frac{2}{5}$	7. $\frac{7}{12}\div\frac{28}{15}$
4. $20\div\frac{5}{4}$	8. $\frac{57}{5}\div\frac{38}{15}$
5. $36\div\frac{5}{15}$	9. $576\div\frac{36}{7}$

DECIMALS

The Decimal Fraction always has a period called the *Decimal Point* at the left. The number of places in the Decimal is the same as the number of zeros in the denominator of the corresponding common fraction.

Thus $\frac{1}{10}$ equals .1; $\frac{6}{10}$ equals .6; $\frac{1}{100}$ equals .01; $\frac{25}{100}$ equals .25; $\frac{1}{1000}$ equals .001.

Notice that the number of zeros in the denominators of the above common fractions is the same as the number of figures to the right of the Decimal Point.

READING DECIMALS

The first place to the right of the Decimal point is *tenths'* place, the second *hundredths'* place, the third *thousandths'* place, the fourth *ten thousandths'* place, etc.

A Decimal is read just as if it were a whole number and is then given the name of the last Decimal place to the right.

Thus, .76 is read "seventy-six hundredths;" .0106 is read "one hundred six ten-thousandths."

Write the following as Decimals:

1. $\frac{4}{10}$; $\frac{6}{100}$; $\frac{6}{10}$; $\frac{9}{10}$; $\frac{47}{100}$; $\frac{79}{100}$; $\frac{3}{1000}$; $\frac{44}{1000}$; $\frac{9}{10,000}$.

2. Write as common fractions—nine-tenths; seven hundredths; eighty-five hundredths; twenty-nine hundredths; twenty-nine thousandths; twenty-nine ten-thousandths.

Mixed numbers are read with the word *and* between the whole number and the decimal. The number 975.3014 is read "nine hundred seventy-five *and* three thousand fourteen ten-thousandths." .275 is read "two hundred seventy-five thousandths," while 200.075 is read "two hundred *and* seventy-five thousandths."

3. Read: .7; 2.4; 90.03; 36.44; 216.5; 15.85.
4. Read: 86.09; 8.001; 60.044; 200.065; .265.
5. Read: 246.0012; 912.2006; 2000.0002; .2002.

CHANGING DECIMALS TO COMMON FRACTIONS

Any decimal may be changed to a common fraction.

Thus .6 equals $\frac{6}{10}$ equals $\frac{3}{5}$.
.25 equals $\frac{25}{100}$ equals $\frac{1}{4}$.
.875 equals $\frac{875}{1000}$ equals $\frac{7}{8}$.
.37½ equals 37½ 100, equals $\frac{75}{200}$ equals $\frac{3}{8}$.

Change to common fractions in the simplest form:

1. .8; .625; .375; .875; .225.
2. 37½; .87½; .12½; .06¼; .62½.
3. .83⅓; .333⅓; .66⅔.

Change the following common fractions to Decimals:

4. $\frac{1}{2}$; $\frac{1}{4}$; $\frac{3}{4}$; $\frac{1}{8}$; $\frac{5}{8}$; $\frac{7}{8}$; $\frac{1}{5}$; $\frac{3}{5}$; $\frac{4}{5}$.
5. $\frac{1}{10}$; $\frac{3}{10}$; $\frac{1}{20}$; $\frac{5}{12}$; $\frac{5}{6}$; $\frac{11}{12}$; $\frac{2}{3}$.
6. $4\frac{1}{8}$; $2\frac{5}{8}$; $3\frac{7}{12}$; $8\frac{1}{3}$; $2\frac{3}{40}$.

ADDITION AND SUBTRACTION OF DECIMALS

Rule.—In adding or subtracting Decimals write the numbers so that the Decimal Points are in the same column and proceed to add or subtract as with integers or whole numbers. Place the Decimal Point in the sum or the difference under the Decimal Points above.

Add the following:

1. 2.25, .75, .1875, .0356.	2.25
	.75
	.1875
	.0356
	3.2231
2. Add: .33 ¼, 35.66 ⅕, 82¾, 1.201 ¼.	.3375
	35.662
	82.75
	1.20125
	127.95075

3. A girl spent for shoes \$4.75, for ribbon \$3.25, for a suit \$30.75 and for the hat \$5.50. What was her total bill?

4. A man owned 320 acres of land. He bought $30\frac{1}{2}$ acres at one time and 12.41 acres at another time. How much had he in all?

MULTIPLICATION OF DECIMALS

Rule.—To multiply when there is a Decimal in either of both factors, multiply as with integers and point off in the product as many Decimal places as are found in both Multiplicand and Multiplier.

1. Multiply 24.6 by 10. Solution:

```
 24.6
   10
-----
246.0
```

2. Multiply 24.6 by 100. Solution:

```
  24.6
   100
------
2460.0
```

Note.—In multiplying a Decimal by 10 the Decimal Point is moved one place to the right; multiplying by 100 moves the Decimal Point two places to the right; by 1000 three places, etc.

3. Multiply .3 by 6.75. Solution:

```
   .3
 6.75
-----
   15
  21
 18
-----
2.025
```

4. Multiply 225.5 by 5.0005.
5. $32\frac{1}{2}$ by 1.0303.
6. .400 by 4.0635.
7. $9.3\frac{1}{3}$ by 9.99.
8. When the average yield of corn is 23.9 bu. per acre and the price is $51\frac{4}{5}$ cents per bu., what is the average value of the corn crop per acre?
9. What will it cost to furnish 224.4 cu. yds. of sand at $\$1.25\frac{1}{2}$ per cu. yd.?

DIVISION OF DECIMALS

Rule.—Provide as many Decimal places in the Dividend as you have in the Divisor by adding zeros if necessary. Divide as in whole numbers and point off as many Decimal places in the Quotient as there are Decimal places in the Dividend less the Decimal places in the Divisor.

1. Divide .095 by .5. Solution:

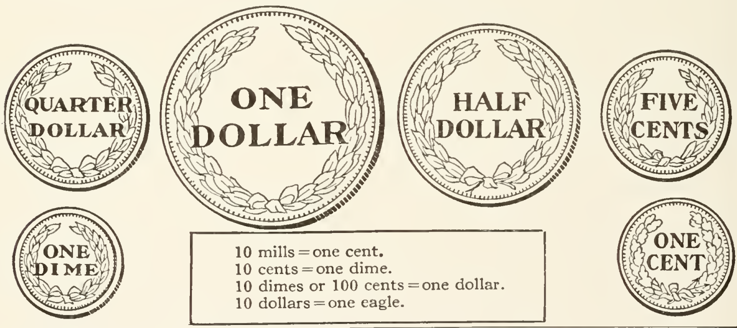
```
.5).095
   -----
    .19
```

2. Divide 110.1 by .1101. Solution:

```
            1000
       ---------
.1101)110.1000
```

3. 1000 divided by .625.
4. 1.045 divided by .56.
5. If a telephone wire is worth \$.002 per ft., what is the value of a telephone wire extending a distance of 5.75 miles?

UNITED STATES MONEY



10 mills = one cent.
10 cents = one dime.
10 dimes or 100 cents = one dollar.
10 dollars = one eagle.

BUSINESS APPLICATIONS OF DECIMALS

The solutions of many problems may be shortened by knowing the relation that the price of a unit bears to \$1.

1. How much will 250 bu. of potatoes cost at \$.25 per bu.?

Decimal Method.

```
$.25  =price
 250=no. of bu.
-----
1250
 50
-----
62.50
```

Short Method.

```
4)250
 -----
 62.50
```

Explanation.—At \$1 each 250 bu. would cost \$250. At $\$\frac{1}{4}$ each they cost $\frac{1}{4}$ of \$250 or \$62.50.

Rule.—Find the cost of the quantity at \$1 per unit, divide this by the quantity that can be purchased for \$1.

Find cost of:

2. 90 bu. apples at $33\frac{1}{3}$c per bu.
3. 32 lbs. butter at 25c per lb.
4. 640 yds. cloth at $6\frac{1}{4}$c per yd.
5. 75 lbs. lard at $12\frac{1}{2}$c per lb.
6. 72 lbs. rice at $12\frac{1}{2}$c per lb.

7. 120 yds. cloth at $37\frac{1}{2}$c per yd.
8. 500 books at 40c each.
9. 600 doz. eggs at 25c per doz.
10. 300 bu. oats at $33\frac{1}{3}$c per bu.
11. 800 bu. coal at $6\frac{1}{4}$c per bu.
12. 80 qts. cherries at $6\frac{1}{4}$c per qt.
13. 500 bu. corn at 40c per bu.
14. 180 lbs. beef at 10c per lb.

DENOMINATE NUMBERS

MEASUREMENTS

Distance, weight, time, liquids, etc., are measured by certain standard units of measure such as feet, pounds, hours, gallons.

LINEAR MEASURE

In measuring length or distance the measures are called Linear Measures.

If you do not know the following table, thoroughly learn it. Use a watch to see how few seconds you need for saying it.

TABLE OF LINEAR MEASURE

12	inches (in.) = 1 foot (ft.).
3	feet = 1 yard (yd.).
$5\frac{1}{2}$	yards = 1 rod (rd.).
320	rods = 1 mile (ml.).
5280	feet = 1 mile.

1. By measuring find the length and the width of your school room or your living room at home, in feet. In yards.

2. Estimate the length of a table. Then measure it and see how nearly right your judgment is.

3. Mark off what you think would be the length of a rod on the floor, and then measure the distance marked.

NOTE.—An expensive tape is not necessary for measuring long distances. Measure off and use a stout cord a rod long or fifty feet long. Every pupil should make many estimates of short and long distances followed by measurements of them to develop accuracy in judging distances.

REDUCTION IN LINEAR MEASURE

Changing any number of units of one denomination to units of another denomination is called *Reduction*.

EXERCISES

1. Reduce 10 miles to rods.
SOLUTION.—10 mi. × 320 = 3200 rods. Ans.
2. 4 rds. to feet.
3. 4 yds. 2 ft. to feet.
4. 2 mi. 248 ft. to feet.
5. 3 mi. 28 rds. to rods.

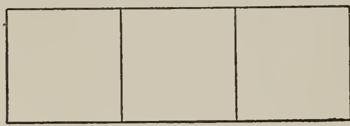
REDUCTION TO HIGHER DENOMINATIONS

1. Reduce 96 in. to feet.
SOLUTION.—96 in. ÷ 12 = 8. Ans.
2. 54 ft. to yards.
3. 72 in. to yards; 288 in. to yards.
4. 15,840 ft. to miles; 1000 rds. to miles and rods.

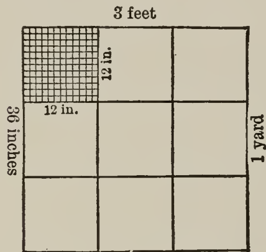
5. Find the cost of digging a ditch $\frac{1}{2}$ mile long at $2.75 a rod.

SQUARE MEASURE

Using your ruler draw upon the blackboard or a paper a square foot. Three square feet, thus:



Mark off all sides of this square foot with inch spaces and draw lines dividing the square foot into square inches. How many square inches in the square foot?



Scale $\frac{1}{24}$. One square yard

Learn thoroughly the following table, using your watch to time yourself.

TABLE OF SQUARE MEASURE

144	square inches (sq. in.) = 1 square foot (sq. ft.).
9	square feet = 1 square yard (sq. yd.).
$30\frac{1}{4}$	square yards = 1 square rod (sq. rd.).
160	square rods = 1 acre (A.).
640	acres = 1 square mile (sq. mi.).

1. The perimeter of a figure is the distance around it. What is the perimeter of your square foot?

2. Draw an oblong 6 inches long and 3 inches wide. Show that it contains 18 square inches.

3. How many square inches in a rectangle 8 inches long and 2 inches wide?

4. How do you find the area of any rectangle or square?

5. Draw figures showing the difference between a 6-inch square and 6 square inches.

6. Draw a square yard and divide it into square feet.

7. How many acres in a field 80 rds. long and 40 rds. wide?

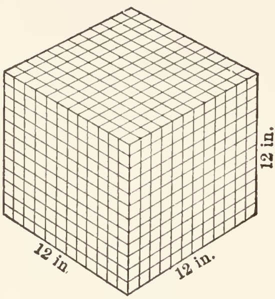
8. What part of a square mile is a field 80 rds. by 40 rds.?
9. A township is six miles long and six miles wide. How many acres does it contain?

PROBLEMS ON PAVING

1. What is the cost of paving a walk 6 ft. wide in front of a 50-ft. residence lot, at 11 cents per foot?
2. What is the cost of paving a walk 7 ft. wide on two sides of a corner residence lot 50 ft. by 150 ft. at 9½ cents per square foot?
3. What is the cost of paving one-half of a 50-ft. street in front of a 50-ft. residence lot at 95 cents per square yard?

CUBIC MEASURE

A cube has *six faces* and each one is a *square*. If each face is a square inch, the cube is called a **cubic inch,** or a one-inch cube.



One cubic foot

Learn thoroughly the following table:

TABLE OF CUBIC MEASURE

1728	cubic inches (cu. in.) = 1 cubic foot (cu. ft.).
27	cubic feet = 1 cubic yard (cu. yd.).
128	cubic feet = 1 cord (for measuring wood).
24¾	cubic feet = 1 perch (for measuring stone).
1	cubic yard = 1 load (of earth).
231	cubic inches = 1 gallon (gal.).
2150.4	cubic inches = 1 bushel (bu.).

Rule.—To find the volume of a solid multiply together the length, breadth and thickness.

1. How many cu. ft. in a pile of wood 8 ft. long, 4 ft. wide, and 4 ft. high?
2. How many cords of wood in a pile 4 ft. wide, 8 ft. high and 32 ft. long?
3. How many gallons of water will a cistern hold which is 6 ft.×10 ft.×10 ft.?
4. A granary is 24 ft. long, 8 ft. wide, and 6 ft. high. How many bushels of wheat will it hold?

LIQUID AND DRY MEASURES

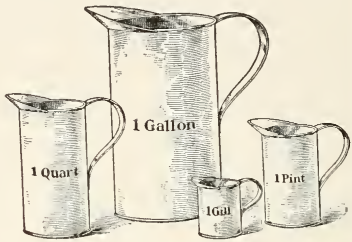
Learn thoroughly the following tables.

TABLE OF LIQUID MEASURE

4	gills (gi.) = 1 pint (pt.).
2	pints = 1 quart (qt.).
4	quarts = 1 gallon (gal.).
31½	gallons = 1 barrel (bbl.).
231	cubic inches = 1 gallon.

TABLE OF DRY MEASURE

2 pints (pt.). = 1 quart (qt.).
8 quarts = 1 peck (pk.).
4 pecks = 1 bushel (bu.).

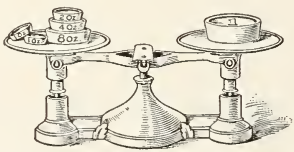


Liquid measures

1. A grocer pays 20 cents a gallon for milk and retails it at 8 cents a quart. If he handles 40 gallons a day how much is his profit?
2. A ship with 1500 passengers aboard carries a supply of 15,000 gallons of fresh water. If each passenger on the average uses two quarts of water a day how long will the supply last?
3. A cistern holds 50 barrels of water. How many gallons is this?
4. How many quart boxes will 4 bushels, 3 pecks, 1 quart fill?
5. What is the cost of 3 pecks, 3 quarts of nuts at 15 cents a quart?
6. If a half-peck basket of peaches sells for 25 cents how much will 4 bushels sell for?

AVOIRDUPOIS WEIGHT

Avoirdupois weight is used in weighing all heavy articles such as farm products, groceries, coal, etc.



16 ounces (oz.) = 1 pound (lb.).
100 pounds = 1 hundredweight (cwt.).
2000 pounds = 1 ton (T.).
196 pounds = 1 barrel (of flour).
280 pounds = 1 barrel (of salt).

NOTE.—The *long ton* (2240 pounds) is used in the United States Custom Houses and in wholesale dealings in coal and iron.

ADDITION AND SUBTRACTION OF DENOMINATE NUMBERS

1. Add 3 hours, 20 minutes; 5 hours, 10 minutes, 20 seconds; and 2 hours, 40 minutes and 42 seconds.

hrs.	min.	sec.
3	20	
5	10	20
2	40	42
11	11	2

42 sec. plus 20 sec. equals 62 sec., equals 1 min. 2 sec. 1 min. plus 40 min., plus 10 min., plus 20 min., equals 71 min., equals 1 hr. 11 min.

1 hr. plus 2 hrs. plus 5 hrs. plus 3 hrs. equals 11 hrs.

The answer is 11 hrs. 11 min. 2 sec.

2. Subtract 5 hours, 29 minutes, 25 seconds from 7 hours, 17 minutes, 47 seconds.

hrs.	min.	sec.
7	17	47
5	29	25
1	48	22

25 sec. from 47 sec. equals 22 sec. 29 min. from 1 hr. plus 17 min. or 77 min. equals 48 min.

5 hrs. from 6 hrs. equals 1 hr.

Ans.—1 hr. 48 min. 22 sec.

3. bu.	pk.	qt.
4	2	5
17	3	3
10	2	6
26	3	5
5	1	3

4. gal.	qt.	pt.
37	2	1
27	2	1
17	3	
28	2	2
27	0	1

5. yd.	ft.	in.
8	2	11
4	1	8
12	4	5
9	1	1
6	0	8

6. From 200 gallons take 49 gallons, 3 quarts and 2 pints.

7. From 45 miles 121 rods, take 25 miles, 75 rods.

8. From 15 yards 2 feet and 2 inches, take 11 yards 1 foot 8 inches.

MULTIPLICATION AND DIVISION

1. Multiply 4 bushels 3 pecks 5 quarts by 4.

bu.	pk.	qt.
4	3	5
	×	4
19	2	4

4×5 qts.=20 qts.=2 pks. 4 qts.

4×3 pks.+2 pks.=14 pks.=3 bu. 2 pks.

4×4 bu.+3 bu.=19 bu.

Ans.—19 bu., 2 pks., 4 qts.

2. Divide 69 feet 4 inches by 8.

	ft.	in.
8)	69	4
	8	8

69 ft. divided by 8=8 with a remainder of 5 ft.

5 ft. (60 in.)+4 in.=64 in.

64 in.÷8=8 in.

3. If a horse eats two pecks of oats a day how long will 60 bushels last him?

NOTE.—Reduce both terms to pecks and divide.

4. If an acre will produce 16 bushels 3 pecks of wheat, how many bushels will 40 acres produce at the same rate?

5. A farmer thrashed 4400 bushels of oats, how many sacks, each holding 3 bushels 4 quarts will be required to contain his crop?

PERCENTAGE

Per cent means per hundred. Thus, 10% means 10 in each 100.

$10\%=.10=\frac{10}{100}$ or $\frac{1}{10}$.

1. 50% of anything is what part of it?
   $50\%=.50=\frac{50}{100}=\frac{1}{2}$.
2. 25% of anything is what part of it?
   $25\%=.25=\frac{25}{100}=\frac{1}{4}$.
3. $12\frac{1}{2}\%=\frac{1}{2}$ of 25% or $\frac{1}{8}$.

It is often convenient in solving problems in percentage to change the per cent to a common fraction. Therefore every pupil should memorize thoroughly the following table.

Table of Equivalents

$\frac{1}{2}=50\%$	$\frac{1}{3}=33\frac{1}{3}\%$
$\frac{1}{4}=25\%$	$\frac{2}{3}=66\frac{2}{3}\%$
$\frac{1}{8}=12\frac{1}{2}\%$	$\frac{1}{6}=16\frac{2}{3}\%$
$\frac{1}{5}=20\%$	$\frac{4}{5}=80\%$
$\frac{2}{5}=40\%$	$\frac{3}{4}=75\%$
$\frac{3}{5}=60\%$	$\frac{3}{8}=37\frac{1}{2}\%$

Other Equivalents Less Important Are

$\frac{5}{6}=83\frac{1}{3}\%$	$\frac{5}{8}=62\frac{1}{2}\%$
$\frac{1}{7}=14\frac{2}{7}\%$	$\frac{7}{8}=87\frac{1}{2}\%$
$\frac{1}{12}=8\frac{1}{3}\%$	$\frac{1}{16}=6\frac{1}{4}\%$

1. Find 25% of 16. Of 24. Of 48.

SOLUTION.—$25\%=\frac{1}{4}$.
$\frac{1}{4}$ of $16=4$.

2. Find 33 1/3% of 24. Of 36. Of 72.
3. Find 66 2/3% of 24. Of 36. Of 72.
4. Find 20% of 40. Of 60. Of 80.
5. Find 40% of 50. Of 60. Of 80.
6. Find 50% of 17. Of 21. Of 34.
7. Find 75% of 12. Of 16. Of 36.
8. Find 80% of 10. Of 20. Of 40.
9. Find 37 1/2% of 16. Of 48. Of 32.
10. Find 30% of 80. Of 40. Of 50.
11. 18 is what % of 24? Of 36? Of 54?

SOLUTION.—$18\div24=\frac{18}{24}=\frac{3}{4}=75\%$.

12. 24 is what % of 48? Of 72? Of 12?
13. 12 is what % of 16? Of 18? Of 84?
14. 25 is what % of 50? Of 75?
15. 35 is what % of 40? Of 42? Of 70?
16. Write as *Decimal Fractions* the following: 5%, 8%, 2%, 12%, 60%.

SOLUTION.—$5\%=\frac{5}{100}=.05$.

17. 80%, 90%, 17%, 15%, 14%.
18. $12\frac{1}{2}\%$, $14\frac{4}{5}\%$, $16\frac{2}{3}\%$, $\frac{1}{2}\%$, $\frac{4}{5}\%$.
19. Express as per cents, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, $\frac{1}{7}$, $\frac{1}{8}$, $\frac{1}{9}$, $\frac{1}{10}$.
20. Express as per cents, $\frac{3}{10}$, $\frac{4}{5}$, $\frac{2}{5}$, $\frac{5}{6}$, $\frac{3}{8}$, $\frac{5}{8}$, $\frac{7}{8}$.

ORAL PROBLEMS

1. A man planted 20% of his 640-acre farm with wheat. How many acres of wheat had he?
2. A man planted 160 acres of corn. His farm contained 640 acres. What per cent of his farm was planted to corn?
3. A man owning a half section of land leaves 25% of it for pasture. How many acres are in pasture?

WRITTEN PROBLEMS

1. In a storm at sea 72% of the 3000 passengers on board an ocean liner were drowned. How many people were lost?
2. A dealer lost 75 bbls. of apples or 15% of all he handled. How many bbls. did he handle?
3. A man bought a lot for $3000 and held it for 2 years, selling it at a gain of 17%. Find the selling price.
4. A man bought a lot for $1600 and sold it for $1400. What was his loss per cent?

INTEREST

Money paid for the use of money is called *Interest.* Interest is a certain per cent of the amount borrowed which latter is called the *Principal.* The per cent charged for the use of the money is called the *Rate.*

ORAL DRILL

1. At 5% how much is the interest on $200 for 1 year? For 6 months? For 2 years? For 2 years 6 months?
2. At 6% find the interest on $400 for 1 year. For 8 months or $\frac{2}{3}$ of a year? For 2 years? For $2\frac{1}{2}$ years?
3. At 4% what is the interest on $800 for 1 year? For 6 months? For 3 months? For 9 months? For a year and 9 months?

WRITTEN EXERCISES

4. At 5% what is the interest on $640 for 2 years 5 months?

SOLUTION: $\frac{29}{12}\times\frac{5}{100}\times 640$ or

$$\frac{29\times5\times640}{12\times100}=\$77.33$$

EXPLANATION.—$\frac{5}{100}$ of $640 equals the interest for 1 year. Two years 5 months equals $\frac{29}{12}$ years, therefore the total interest equals $\frac{29}{12}\times\frac{5}{100}\times640$. Use cancellation whenever possible.

5. Find the interest of $250 at 4% for 1 year 4 months.
6. Find the interest of $500 at 5% for 1 year 3 months.
7. Find the interest of $750 at 4% for 2 years 2 months.
8. Find the interest of $124 at 6% for 1 year 9 months.
9. Find the interest of $436 at 5% for 2 years 8 months.

NOTE.—In the above problems no days are given. But where the time of the problem has days, reduce the time to days as a numerator over 360 days.

10. Find the interest of $6500 at 6% for 3 months 20 days.

SOLUTION: 3 months 20 days = 110 days.

$$\frac{110}{360}\times\frac{6}{100}\times\$6500=\$119.17.$$

11. Find the interest of $650 at 5% for 70 days.
12. Find the interest of $135 at 5% for 8 months 20 days.
13. Find the interest for $486 at 4% for 90 days.

THE BANKERS' METHOD OR THE 60-DAY METHOD OF FINDING INTEREST

Money is often borrowed for short periods especially at banks for 30, 60 or 90 days. Six per cent is a very usual rate in such cases. The method used is as follows:

The interest of any Principal at 6%:
For 360 days = 0.06 of the Principal.
For 60 days = 0.01 of the Principal.
For 6 days = 0.001 of the Principal.

14. Find the interest of $660 at 6% for 90 days.

SOLUTION: Interest for 60 days = $6.60
For 30 days = 3.30
Total interest $9.90

EXPLANATION.—Since $\frac{1}{100}$ of $660 or $6.60 is the interest for 60 days and 30 days equals half as much, or $3.30, the total interest must be their sum.

Find the interest at 6% of:

15. $1080 for 60 days.
16. $720 for 90 days.
17. $840 for 30 days.
18. $960 for 10 days.
19. $480 for 45 days.

Find the interest at 6% of:

20. $1440 for 87 days.

SOLUTION: $14.40 = interest for 60 days.
4.80 = interest for 20 days.
1.20 = interest for 5 days.
.48 = interest for 2 days.
$20.80 87 days.

21. $2400 for 50 days.
22. $1500 for 120 days.
23. $2750 for 63 days.
24. $840 for 84 days.
25. $3040 for 108 days.

Note that the foregoing problems all bear 6%. This method may be used with problems bearing any per cent.

26. At 5% find the interest of:
$1680 for 75 days.

SOLUTION:

$16.80 = the interest at 6% for 60 days.
4.20 = the interest at 6% for 15 days.

6)$21.00 = the interest at 6% for 75 days.

$ 3.50 = the interest at 1% for 75 days.
17.50 = the interest at 5% for 75 days.

27. $1640 for 70 days.
28. $1900 for 63 days.
29. $1750 for 72 days.

TAXES

Towns, cities, counties and states meet most of their expenses by levying taxes upon the property within their limits.

For purposes of taxation property is divided into two classes, Real Estate and Personal Property.

Real Estate is immovable property such as land including mines, quarries, forests, railroads and buildings.

Personal Property is movable property such as money, stocks, bonds, household goods, cattle, etc.

Some states also levy a tax on all male citizens over twenty-one years old. This is called a *Poll Tax.*

Name some ways in which your city or county spends its tax money.

METHOD OF SPREADING TAXES

Officers called *Assessors,* first inspect property and place a value upon it for taxation. Then the city, township, school district or county determines the amount of money needed to run the government for one year. The total amount of money needed is divided by the total value of the property as fixed by the Assessor. This gives the amount of tax on one dollar or the rate of taxation.

Thus if a school district needed $20,000 to run its schools for 1 year while the property in the district was valued by the Assessor at $2,000,000, the rate would be $20,000 ÷ $2,000,000 = .01, which is the rate of taxation for school purposes.

1. If the Taxes are 18 mills on $1, what rate per cent are the Taxes? How much are the Taxes on property valued at $15,000?

2. My property is assessed at $5000, the Tax rate is 1½%. What are my annual Taxes?

3. What would be the Tax on a farm assessed at $6000 if the rate is .007? If it is .0102?

4. Mr. Jones owns a house valued at $24,000 which is assessed at 2/3 of its value. The Tax rate is .022. What will be his total Tax?

5. If Mr. Jones pays his Tax within thirty days he receives a discount of 2%. How much will he save by paying his Taxes promptly?

PROPERTY INSURANCE

A man who does not wish to bear the total loss of his house in case of fire pays an *Insurance Company* a certain per cent for the Insurance of his property. The amount paid is called the *Premium.*

The Insurance Company agrees to make good his loss to the extent of the sum named in the *Policy* or contract with him in case his house is accidentally burned during the period covered by the Policy.

Insurance Companies do not usually insure property for its full value. Can you give a reason why?

1. The school house is insured for $10,000 for three years. The Board of Education has to pay the Insurance Company 50% for this. What is the face of the Policy? What per cent of the face of the Policy is the Premium? What per cent is this a year?

2. I value my house at $10,000. The Company insures it for 3 years at half its value at ¾% of the face of the Policy. How much will the Premium cost?

3. A business block costing $40,000 is insured for 3 years for ½ its value at 1% a year. What is the total Premium?

4. A hotel is insured for $10,000 in each of five different companies. The total Premium is $1000. Find the rate of insurance.

5. A factory worth $80,000 is insured for ¾ of its value at 1⅞%. In case of total loss by fire find the owner's loss, including Premium paid out.

COMMISSION

The value of property.—City property varies greatly in price depending upon the city and upon whether the property is used for residence for business blocks, or for factories. The distance from street cars or other means of transportation affects the value of property. City lots are valued at so much per front foot.

The width of a lot measured along the street is its *Frontage,* while the distance from the street to the rear of the lot is called its depth. If it is worth $20 per front foot that means $20 for a strip one foot wide at the street and reaching back to the rear of the lot. The deeper the lot the more area it covers and the more desirable it is, other things being equal. When one speaks of a 100-foot lot, one means a lot with 100 feet frontage.

Residence lots vary in frontage from 30 feet in poorer sections to 150 feet or more in the best residence districts. In depth they may be from 100 feet to 200 feet or more. The price of residence lots varies in different cities and in different districts of the same city from $15 or $20 to $200 or more per front foot.

1. What are vacant lots near your home valued at per front foot? At that rate what is an 80-foot lot worth?

2. Who pays for laying sidewalks in front of a property? Who pays for paving the street and laying the sewer? See if you can find out how much it costs per front foot to do these things on your street.

PRACTICAL PROBLEMS AND CALCULATIONS

EDUCATION AND INDUSTRY

It has been carefully estimated that a man with a common school education is able to produce on the average $1\frac{1}{2}$ times as much wealth as an unschooled man; the high school man can produce 2 times as much, and the college man 4 times as much as the untrained mind.

If a laborer who can neither read nor write is able to earn $14 a month, how much more should he earn in a period of 40 years if he had started with a common school education? Ans.—$3360.

How much more would he have accumulated in the same time if he had obtained a high school education? Ans.—$13,440.

What will be the difference in the earnings of two men for a work period of 40 years, one with a college education who earns $1000 a year and the other with a common school education who earns $450 a year? Ans.—$22,000.

A boy who knows how to handle and care for tools saves in this way 5 cents for every work day he lives. What is this training worth to a man in the course of 40 years if there are 26 working days in each month? Ans.—$624.

A boy who has been trained in the use of tools saves $20 a year in the repairs and convenient articles made for the home. What does this amount to in 40 years? Ans.—$800.

A self-binder costing $125 would have lasted with good care 12 years. It was left out in the weather and lasted only 3 years. What did the farmer's carelessness cost him? Ans.—$93.75.

If a careless hired hand while cultivating corn covers up 20 hills to the acre, what is the value of the corn destroyed on a 20-acre field, counting 2 ears to a hill and 100 ears to the bushel when corn is worth 50 cents a bu.? Ans.—$4.

FENCING

Data.—Barbed wire is sold by the roll, weighing about 100 lbs. and containing about 1200 ft. of wire. In a pound of staples there are about 100.

Note.—Always draw the form of the field before attempting to solve the problem.

How much wire fencing will it take to fence an acre lot in the form of a square, 12 rods, 10 ft., 9 in. each way? Ans.—50 rods, 10 ft.

How much fence will it take to enclose an acre lot which is 20 rods long and 8 rods wide? Ans.—56 rods.

A 40-acre field is 80 rods each way. Find cost of posts and fencing with three strings of barbed wire at 25 cents a rod and a 12-foot gate worth $5. Ans.—$85.

Another 40-acre field is 160 rods long and 40 rods wide, how much more will the fence cost than in the previous problem with the posts, fence and gate at the same price? Ans.—$20.

How much more will the fence posts cost for the 40-acre tract 160 rods by 40 rods than for the same acreage in the form of a square if the posts cost 8 cents each and are placed 1 rod apart, one extra being necessary for the gate? Ans.—$6.40.

How many acres of land in a field 80 rods wide and 120 rods long? How many rods of fencing are needed to enclose it? Ans.—60 acres; 400 rods.

How many rods of fencing are required per acre in the above problem? Ans.—5 rods.

How many acres of land in a field 40 rods square? Ans.—10 acres.

How many rods of fencing are needed to enclose a field 40 rods square? Ans.—160 rods.

How many rods of fencing are required per acre in a field 40 rods square? Ans.—16 rods.

If the fencing costs 30 cents a rod and lasts 10 years, what is the yearly cost per acre? Ans.—30 cents an acre per year.

How much is the annual cost per acre of such a fence if $10\frac{2}{3}$ rods of fence are required to enclose an acre? (See above problem.) Ans.—32 cents per acre per year.

What does it cost for posts worth 12 cents each to build 120 rods of fence if the posts are set $1\frac{1}{2}$ rods apart? Ans.—$9.60.

CORN

How to Test Seed Corn.—Make a box 36 in. by 40 in. and 3 in. deep. Fill the box about half full of moist dirt, sand or sawdust. Press it down so that it will have a smooth, even surface.

Take a white cloth about the size of the box, rule it off into squares 3 in. each way, numbering them 1, 2, 3, 4, etc., and place it in the box upon the sand. Take 6 kernels from each ear and place in one square, giving the ear the same number. Cover with a moist pad stuffed with sawdust and keep moist and warm for several days.

How many days did corn planted May 10 have to mature if frost occurred on the night of September 10? Ans.—123 days.

When corn is planted May 15 and frost comes on the night of September 1, how many days has the corn in which to mature? Ans.—108 days.

A bushel of seed corn will plant 7 acres. When seed is selling at $2 a bu., what is the cost of seed per acre? Ans.—28 4/7 cts.

If extra good seed corn costs $4.50 a bu., what will it cost per acre? Ans.—64 2/7 cts.

If it costs 14 cts. a bu. to grade seed corn with a corn grader and a bu. of corn will plant 7 acres, what is the cost per acre for grading the seed? Ans.—2 cts.

If a man spends 4 hours shelling off tip and butt kernels and sorting irregular kernels from a bu. of seed corn, how much will it cost him per acre if his time is worth 15 cts. an hour? Ans.—8 4/7 cts.

If it requires 18 ears of corn to plant 1 acre, how many ears would be needed to plant $12\frac{1}{2}$ acres? Ans.—225 ears.

Corn on the ear weighs 70 lbs. a bu. If the ears average 10 oz. each, how many ears in a bu.? Ans.—112 ears.

If the ears average 12 oz. each, how many ears in a bu.? Ans.—93 plus ears.

If a man can select 1120 ears of seed corn averaging 10 oz. each in 3 days, how much will it cost him a bu. if his time is worth $2 a day? Ans.—60 cts.

What are 1120 ears of seed corn worth at $2.50 a bu. if the ears average 10 oz. and there are 70 lbs. in a bu.? Ans.—$25.

Corn is sometimes reckoned on the basis of 120 ears to the bu. What is the weight of such corn per ear? Ans.—9⅓ oz.

If corn is planted in check rows 3 ft. 8 in. apart each way, how many square feet does each hill of corn occupy? How many hills on an acre? Ans.—13$\frac{4}{9}$ sq. ft.; 3240 hills.

How many stalks are there on an acre when they are planted 3 stalks in a hill 3 ft. 8 in. each way? Ans.—9720 stalks.

If the stand is perfect and each stalk produces one ear, what is the yield per acre, 120 ears to the bu.? Ans.—81 bu.

A bushel of choice seed corn costing $3.50 a bu. will plant 7 acres in check rows. What is the cost of the seed for 20 acres? Ans.—$10.

A poorer quality of seed will be priced at $1.50 a bu. How much less will it cost for the same 20 acres? Ans.—$4.29.

After shelling off the irregular kernels on the butt and tip of a certain ear of corn there are 38 kernels left in each row. If there are 20 rows on the cob how many hills will it plant, placing 3 kernels in a hill? Ans.—253 hills.

DRAINAGE

All tile are 1 foot long. The average price is about 3 cents each for 3-in. tile, 4 cents each for 4-in. tile and 5 cents each for 5-in. tile.

A tract of wet land of 17 acres was tile-drained at a cost of $24 an acre. What was the cost of draining the field? Ans.—$408.

The farmer then sowed it to wheat, harvesting 45 bu. an acre, which sold for one dollar a bushel. What was his gross income from the wheat crop? Ans.—$765.

If the farmer cleared 33⅓ cts. a bu. from his wheat crop, of 45 bu. an acre each year, what would be his net gain in 5 years after deducting the cost of tiling? Ans.—$867.

Mr. Brown had a square piece of low land containing 90 acres. When he prepared to tile it he found it was 6 ft. 8 in. higher at one side than at the other. How wide is the field? How much fall will this be to the rod? Ans.—120 rods wide; 1½ in. to the rod.

What did it cost to lay 6 strings of tile across this 90-acre tract if the tile is $20 a thousand and each tile was 1 ft. long and the cost of laying them was 30 cts. a rod? Ans.—$453.60.

Find the cost per acre for tiling. Ans.—$5.04.

If tiling Mr. Brown's field increased the yield of corn an average of 8 bu. per acre, what will the increase of corn be worth on the 90 acres at 40 cts. a bu. in 10 years? Ans.—$2880.

What will be the net gain per acre over the cost of tiling in 10 years? The net gain on the 90-acre tract? Ans.—$26.96 an acre; $2426.40.

Farmer Jones had 20 acres of orchard with 30 trees on each acre. Each tree yielded on the average 2 bbls. of apples worth $3 a bbl. After tile-draining his orchard at a cost of $30 an acre, his income from the crop was doubled. What fraction of the crop paid for the tiling? Ans. $\frac{1}{12}$ of the crop.

PLOWING

There are 160 sq. rds. in an acre. How many acres in a field 80 rods square? Ans.—40 acres.

How many acres in a field 8 rods wide and 20 rods long? Ans.—1 acre.

A ten-acre field is 40 rods long. How many feet wide is it? Ans.—660 ft.

A five-acre field is 16 rods wide; how long is it? Ans.—50 rods.

How many times must a farmer cross a field 40 rods square with a harrow 12 ft. wide to harrow the field? Ans.—55 times.

How far will the farmer travel in the above problem? Ans.—6⅞ miles.

How many times must Mr. Brown cross a field 16 rods wide with a 12-foot harrow to harrow the field? Ans.—22 times.

How many rounds (back and forth) must Mr. Brown make to plow a field 8 rods wide if the plow turns a furrow 14 in. wide? Ans.—57 rounds.

How far must the plowman, cutting a 14-in. furrow travel to plow an acre 8 rods wide, not counting the turns? Ans.—7⅛ miles.

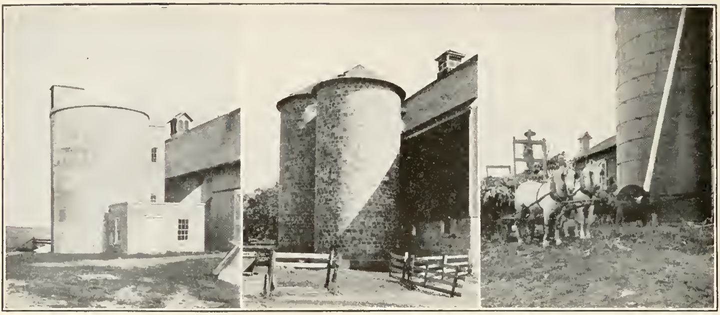
How far must one travel with a 12-foot harrow to harrow an acre? Ans.—220 rods.

How far must a team travel, not counting the turns, to plow one round on a field 40 rods long? Ans.—¼ mi.

To plow a strip 10 rods wide, how many furrows must be plowed with a 14-in. plow? Ans.—142 furrows.

How far must a team travel to plow a field 20 rods square with a 14-in. plow? Ans.—17$\frac{11}{16}$ mi.

A man with two horses and a 14-in. plow plows 2 acres in 8 hours. What does it cost to plow one acre if the man's time is worth 16 cts. an hour and the time of each horse is worth 8 cts. an hour?—Ans.—$1.28.



SILOS

The base of a silo is 20 ft. in diameter. Find its circumference. Ans.—$62\frac{6}{7}$ ft.

Find the capacity in cu. ft. of a silo 16 ft. in diameter and 30 ft. high. Ans.—$9428\frac{4}{7}$ cu. ft.

If a cu. ft. of silage weighs 30 lbs., how many tons will this silo contain if after it is settled the silage is 4 ft. from the top? Ans.—122 .5 T.

A silo is 18 ft. in diameter and 32 ft. high; how many tons of silage does it hold if a cu. ft. weighs 36 lbs. and it has settled 4 ft. from the top? Ans.—123.3 T.

If 45 cows are fed 36 lbs. each of silage a day, how long will the contents of the above silo last this herd? Ans.—158 days.

What must be the diameter of a silo 36 ft. deep filled with silage to within 4 ft. of the top to hold enough silage to feed 24 cows 35 lbs. a day for each cow for 180 days if the silage weighs 36 lbs. a cu. ft. Ans.—13 ft, nearly.

How many acres of corn will it take to supply ensilage to a herd of 24 cows for 180 days, 35 lbs. each per day, if 1 acre yields 12 T. of silage? Ans.—7 acres, nearly.

The corn on a field of 24 acres when ready for cutting and chocking, or for putting in the silo, weighs 10 tons per acre, of which 80% is water. By cutting and shocking the corn there is a loss in dry matter of 30%; by putting it in the silo there is a loss in dry matter of only 10%; if the dry matter in silage is worth \$.0071 a lb., what is the value of the feed gained by putting the crop in the silo? Ans.—\$136.32.

A silo 16 ft. in diameter is filled 24 ft. deep with silage. One cu. ft. weighs 30 lbs. How many tons of silage are in the silo? Ans.—144.8 T.

HAY

One acre of mixed clover and timothy will produce $2\frac{1}{2}$ tons of hay. If the labor to raise it costs \$3.68 an acre and the rent of the land is \$2.50 an acre, what is the total cost per ton? Ans.—\$2.47.

If the above crop yields but $1\frac{1}{2}$ tons an acre what is the cost per ton for producing it? Ans. —\$4.12.

If bran is worth $2\frac{1}{2}$ times as much as clover hay per pound, how much is bran worth when clover is \$8 a ton? Ans.—\$20.

If it costs a farmer only \$3.34 a ton to raise clover hay, how much can he afford to pay for bran which is worth $2\frac{1}{2}$ times as much as clover hay? Ans.—\$8.35 a ton.

If a 12-acre field of clover yields 3500 lbs. of hay per acre at the first crop, and a bushel of seed per acre at the second crop, what is the entire yearly income from the field when hay is \$10 a ton and seed \$8 a bu.? Ans.—\$306.

At \$8 a bu. what is the return from 5 acres of clover yielding 160 lbs. of seed an acre (60 lbs. to the bu.). Ans.—$\$106.66\frac{2}{3}$.

If an acre of clover yields 4500 lbs. of clover hay the first cutting and 2400 lbs. the second cutting, what is the value of the crop at \$8 a ton? Ans.—\$27.60.

One pound of alfalfa hay contains .11 of a pound of digestible protein, .4 of a pound of carbohydrates, and .012 of a pound of fats. Red clover hay contains .068 lb. protein, .36 lb. carbohydrates and .017 lb. fats. What is the difference in the feeding value of a ton of alfalfa and a ton of red clover when digestible protein is worth 3 cts. a lb. and carbohydrates 1 ct. a pound and fats $2\frac{1}{2}$ cts. a pound? Ans.—Alfalfa \$15.20 per ton; red clover \$12.13.

One pound of timothy hay contains .028 lb. digestible protein, .43 lb. C. H., and .014 lb. fat. Which has the greater feeding value, timothy or clover according to the above problem? Ans.—Clover, \$12.13; timothy, \$10.98.

ORCHARDS AND SPRAYING

When trees are set 25 ft. apart each way, how much space does each tree occupy and how many trees can be set on an acre 10 rods by 16 rods? Ans.—60 trees.

(NOTE.—Find how many trees in a row and the number of rows.)

If the acre lot is square how many trees may be set on it 25 ft. each way? Ans.—64 trees.

If there are 64 trees per acre and each tree produces 3 bu. 3 pk. of apples, how much are the apples on one acre of orchard worth at 75 cts. a bu.? Ans.—\$180.

The Kentucky Experiment Station made a spraying test on an orchard that had never before been sprayed. One sprayed Maiden Blush tree yielded 7 bu. of apples, $4\frac{1}{2}$ bu. of which graded firsts and sold at 75 cts. a bu., the remainder graded seconds and sold at $37\frac{1}{2}$ cts. One unsprayed tree of the same variety in the next row yielded 4 bu. of apples, $\frac{1}{2}$ of which graded firsts and the rest seconds. What is the difference in income from the fruit on the two trees? Ans.—$2.625.

If an orchard contained 200 trees, what would be the difference in income from a sprayed and an unsprayed crop according to the data in the above problem if firsts sold at 50 cts. a bu. and seconds at 30 cts.? Ans.—$340.

Bordeaux Mixture contains 4 lbs. of freshly slaked lime and 4 lbs. of copper sulphate or bluestone in 50 gals. of water; with lime at 1c. a pound, and copper sulphate at 10 cts. a pound, what would it cost to spray 200 apple trees twice if 2 gals. of the mixture is sufficient for the spraying of one tree once? Ans.—$7.04.

Three unsprayed apple trees yielded 188 sound apples while 6 similar trees, sprayed, yielded 8764 sound apples. Counting 100 apples to the bushel, what would be the gain from spraying 100 trees when apples are selling at 80 cts. a bu.? Ans.—$1118.40.

FEEDING

If a calf weighs at birth 55 lbs. and gains 2 lbs. a day, what should it weigh under usual conditions at the end of 90 days? Ans.—235 lbs.

When milk is worth 15 cts. a gal., what is the cost of making a calf that weighs 60 lbs. at birth weigh 140 lbs. when it takes $1\frac{1}{4}$ gals. of milk to produce one pound of his weight? Ans.—$15.

Which is the better proposition, to keep a young calf for 90 days, feeding it on the average $2\frac{1}{2}$ gals. of milk a day worth 10 cts. a gal., and then sell it for $15; or to sell it at birth for $3 and sell butter-fat from the milk at 18 cts. a pound if the milk contains 3.8% butter-fat and a gal. of milk weighs 8.6 lbs.? Ans.—First proposition, loss $7.50; second, gain $8.88.

A calf at birth weighs 68 lbs. If at the end of 60 days it weighs 200 lbs., what is the cost of its keep, not counting labor, if $1\frac{1}{4}$ gal. of milk worth 15 cts. a gal. produces 1 lb. of weight? Ans.—$24.75.

At an Experiment Station a certain pig that was fed a total of 397 lbs. of shelled corn gained 79 lbs. At this rate how many pounds of shelled corn did it take to produce one pound of flesh? Ans.—5 lbs. corn.

When corn is 50 cts. a bu., what does it cost to add one pound of flesh to a pig according to the above problem (56 lbs. to a bu.)? Ans.—$4\frac{6}{11}$ cts.

At this rate how many pounds of fat can be put on a hog with a bushel of corn weighing 56 lbs.? Ans.—11 lbs.

Another test showed that pigs fed for 46 days on a total of 334 lbs. of middlings gained 90 lbs. At this rate how many pounds of middlings does it take to put one pound of flesh on a hog? Ans.—3.7 lbs.

Compare the cost of producing one pound of live weight on a hog with corn at 45 cts. a bu. with middlings at $1.40 a cwt. Ans.—Corn $4\frac{1}{11}$ cts; middlings $5\frac{5}{27}$ cts.

ROADS

Farmers living in regions where they have good roads are enabled to haul their products to market at any season of the year. Larger loads can be drawn in less time. This reduces the cost of marketing crops. A good road must be hard and smooth with proper slope for drainage.

If a road is 66 ft. wide, how many sq. ft. of surface are there in a mile of road? Ans.—348,480 sq. ft.

If a road bed is 12 ft. wide, how many square feet of surface in a mile? Ans.—63,360 sq ft.

If there are 32 in. of rainfall in a year, how many tons of water fall on a mile of road 66 ft. wide, in a year? Ans.—3833.28 T.

How many cu. yds. of gravel are required to cover a mile of road bed 10 ft. wide and 6 in. deep? Ans.—$977\frac{7}{9}$ cu. yd.

If it costs 50 cts. a sq. rd. for grading, what will it cost to grade a mile of road-bed 10 ft. wide? Ans. $96.93.

If a team can be hired for $4 a day of 10 hrs. each which can haul a cu. yd. of gravel an hour, how long will it take to gravel a 12-foot road-bed a mile long with gravel 6 in. deep? What will it cost? Ans.—$469.33.

An apple grower had 1200 tons of apples to deliver to the railroad 6 miles away. It is estimated that poor dirt roads cost the marketer 17 cts. a ton for every mile. In this region the roads were well-kept and the cost was only 13 cts. a mile. How much does this grower save on his crop by the good roads? Ans.—$288.

According to the above problem, what does it cost Mr. Carter to market 60 tons of produce at a distance of 6 mi. on poor dirt roads? Ans.—$61.20.

Mr. Bangs goes to market twice a week. The market is 10 miles away. Over poor roads a whole day is consumed. Over macadamized roads he can make the round trip in half a day. How much would macadamized roads save this farmer in a year if the time of himself and his team is worth $2 a day? Ans.—$104.

RENTS

Property owners usually charge their tenants 10% of the value of the house and lot as rent. Out of this gross rental the owner pays the taxes, insurance and the necessary repairs. These three items average about $\frac{1}{5}$ or 20% of the gross rental.

Real estate agents charge from $2\frac{1}{2}$% to 5% of the gross rental as commission for renting a house for an owner. For selling of property agents charge from $2\frac{1}{2}$% to 5% of the selling price of the property for their services.

For what would a man owning a $10,000 house on an average lot be likely to rent it?

WHEAT

How many bushels in 13,620 lbs. of wheat if there are 60 lbs. in a bushel? Ans.—227 bu.

How many pounds are produced on $12\frac{1}{2}$ acres yielding 20 bu. per acre? How many bushels? Ans.—15,000 lbs.; 250 bu.

If there are 12 lbs. of water in 100 lbs. of wheat, how many pounds of water in 25 bushels? Ans.—180 lbs.

If $\frac{7}{10}$ of wheat is starch, how many lbs. of starch in 25 bu.? Ans.—1350 lbs.

How many tons of wheat are grown on 24 acres yielding 24 bu. per acre? Ans.—17.2 tons.

What is the value of the crop in the above problem at 85 cents a bushel? Ans.—$489.60.

It takes 4.77 bu. of wheat to make one bbl. of flour. How many bbls. of flour can be made from a 20-acre field of wheat averaging 15 bu. to the acre? Ans.—62.9 bbls.

If 60 acres are seeded to wheat and only $\frac{4}{5}$ of the seed germinates, how many acres are seeded to wheat that will not grow? Ans.—12 acres.

At 85 cts. a bu. and with a crop of 24 bu. per acre, what is the value of the wheat grown on a piece of land containing 280 sq. rds.? Ans.—$35.70.

If wheat for sowing contains $\frac{1}{20}$ weed seed, how much land will a farmer sow to weeds if he plants a 40-acre field? Ans.—2 acres.

What will be his loss if by sowing clean seed wheat his field would have yielded 25 bu. an acre worth 75 cts. a bu.? Ans.—$37.50.

If 25 bu. of 85-cent wheat can be grown on an acre, how many pounds is that per acre and what is the price per pound? Ans.—1500 lbs.; $1\frac{1}{4}$ cts.

BIRDS AND INSECTS

If the damage done by insects on a farm averages 60 cts. an acre for the entire farm, what would this amount to on a 240-acre farm? Ans.—$144.

Winter birds live on weed seed. If each bird eats a quarter of an ounce of weed seed in a day and there is a bird to each acre, how many pounds of weed seed will the birds eat on 320 acres in 3 months? Ans.—450 lbs.

Wild birds average about 400 to a quarter section of 160 acres. How many would this be for a township 6 miles square (36 sections)? Ans.—57,600 birds.

It is estimated that 500 small grasshoppers will eat a pound of a growing crop in one day. If a meadow lark eats 250 grasshoppers in a day, how many larks can save a ton of a growing crop in 10 days? Ans.—40 larks.

A stalk of plantain bears an ounce of seed or about 14,000 seeds. If 40 seeds sow one square yard of ground, what part of an acre will one stalk of plantain sow? Ans.—$\frac{35}{484}$ A.

If 4 lbs. in every bushel of a farmer's crop of oats is weed seed, what per cent of his crop of 2000 bu. is weeds? How many pounds of oats? Ans.—$12\frac{1}{2}\%$; 46,000 lbs. oats.

If a farmer seeded 20 acres of land with grass seed containing 10% weed seed, how much land would he sow to weeds? Ans.—2 acres.

Twelve bu. of clover seed containing $4\frac{1}{2}$ bu. of dead seed were bought at $3.75 a bu., what was the price paid for the live seed? Ans.—$6.

Twenty bushels of clover seed containing $1\frac{1}{2}$ bu. of dead seed were bought for $6 a bu. What was the price paid for the live seed? Ans.—$6.49.

COWS, MILK AND BUTTER

Four per cent milk means that each 100 lbs. of milk contains 4 lbs. of butter fat.

Process: 100 lbs.×.04=4 lbs.

How many lbs. of butter-fat in 4000 lbs. of milk that tests 5%? Ans.—200 lbs.

How much less is the butter-fat if the milk tests 3%? Ans.—80 lbs.

A cow gives on an average 18 lbs. of 4% milk per day for 300 days each year. What is her yearly butter-fat production? Ans.—216 lbs.

When a cow yields 20 lbs. of milk daily which tests 3.2% butter-fat, what quantity of butter-fat is produced in a month of 30 days? How much is it worth at 28 cents a lb.? Ans.—19.2 lbs.; $5.376.

A cow gives 5400 lbs. of milk in a year testing 3% fat. How much is it worth at 28 cts. a lb.? Ans.—$45.36.

If a cow gives 5400 lbs. of milk in a year testing 5% fat, how much is the butter-fat worth at 28 cents a lb.? Ans.—$75.60.

A dairyman owns a herd of 12 cows that average 24 lbs. of milk each day from each cow. How many lbs. of milk does he get in a month of 30 days? Ans.—8640 lbs.

If this milk tests 3.8% and butter-fat is worth 28 cts. a pound, what does he receive monthly from his herd? How much per head? Ans.—$85.36; $7.11 per head.

The average cow gives about 4000 lbs. of milk in a year testing about 3.8% fat. How many lbs. of butter-fat does she give? What is it worth at 30 cts. a lb.? Ans.—152 lbs.; $45.60

If every farmer fed and cared for his cows in the best possible manner, the average yield of dairy cows would be increased about 100 lbs. of butter-fat for each cow per year. If butter-fat is worth 30 cts. a lb., how much more income would a farmer receive from a herd of 10 cows with extra care? Ans.—$300.

From the following record find the monthly income from each cow, with butter-fat at 25 cts. a pound. Which is the best cow and which the poorest?

	Daily Yield of Milk	Fat Test
Brindle	32 lbs.	3.5%
Brownie	16 lbs.	4 %
Rose	28 lbs.	3.5%
Cherry	18 lbs.	3 %
Red	15 lbs.	3.2%
Daisy	26 lbs.	5.4%

Ans.—Daisy, $10.53; Brindle, $8.40; Rose, $7.35; Brownie, $4.80; Cherry, $4.05; Red, $3.60.

At the Chicago Dairy Show, November, 1913, the U. S. Government displayed a herd of cows whose feed was carefully weighed and whose milk was weighed and tested. Below is the week's record tested for butter-fat of 3 of the cows in that herd. The cows were said to have freshened about the same time.

	Lbs. of Milk in 7 days	Av. % of butter-fat	Cost of feed
Grade, or scrub cow	49.6	4.6%	$1.44
Guernsey	235	6.5%	1.78
Holstein	350	3.8%	1.94

Find the amount of butter-fat produced by each cow during that week. Ans.—Grade, 2.8 lbs.; Guernsey, 15.2 lbs.; Holstein, 13.3 lbs.

Find the week's income from each cow with butter-fat at 33 cts. a pound. Ans.—Grade, $0.93; Guernsey, $5.02; Holstein, $4.39.

Find the weekly profit or loss after charging each cow with her feed. Ans.—Grade, loss $0.51; Guernsey, profit, $3.53; Holstein, $5.25 profit.

A dairyman sent to market 200 lbs. of 25% cream. From what quantity of 5% milk was the cream taken? Ans.—1000 lbs.

His neighbor sends with him 200 lbs. of 20% cream which was taken from 1000 lbs. of milk. What was the per cent of fat in this milk? Ans.—4%.

The temperature of cream ready for churning may vary from 50 degrees Fahr. to 66 degrees. As the temperature increases above 66 degrees Fahr. more butter-fat is left in the milk. The butter is also soft and of an inferior quality. This cream churns more slowly than thick cream. Churning should be stopped when the granules are about the size of a grain of wheat of large size.

Buttermilk churned from cream at a temperature of from 50 degrees to 60 degrees contains .2% of fat, when churned at a temperature of from 75 degrees to 80 degrees the buttermilk tests .9% butter-fat. What would be saved by churning at the lower temperature from a herd of cows from which 16,400 lbs. are annually produced? Ans.—114.8 lbs.

From the following record find the monthly income from each cow, with butter-fat at 25 cts. a pound. Which is the best cow and which the poorest? Arrange them in the order of the money income they produce.

A certain farmer has 15 good butter cows. The average per cent of butter-fat for the entire herd is 5.5%. If they yield 240 lbs. of milk on an average daily, what is the average daily production of butter-fat in pounds. Ans.—13.2 lbs.

What is the daily income from such a herd when butter-fat sells for 28 cts. a pound? Ans. —$3.70.

A certain farmer owned a Holstein cow that was very valuable but he did not know it because he had never tested her milk. He traded her for a scrub cow and $15. The Holstein was tested and found to give 800 lbs. of butter-fat in a year and the scrub, 125 lbs. What did the farmer lose in 5 years with butter-fat at 25 cts. a pound if both cows consumed the same amount of feed? Ans.—$843.75.

A farmer with a herd of Jersey cows numbering 10 had the week's weight of milk as follows: 210 lbs., 220 lbs., 212 lbs., 214 lbs., 204 lbs., 216 lbs., and 214 lbs. for each day. It tested 6% butter-fat which sold at 28 cts. a pound. How much did the cows average per head for the week? Ans.—$2.50.

A dairyman hauls 24,650 lbs. of milk that tests 3.8% to a creamery. The price of butter-fat is 30 cts. a pound; how much money should he receive? Ans.—$281.01.

POTATOES

A bushel of potatoes weighs 60 lbs.

If an acre of potatoes yields 110 bu. what is the value of the crop at 40 cts. a bu.? Ans.—$44.

How many pounds of potatoes are grown on $2\frac{1}{2}$ acres yielding 150 bu. per acre? Ans.—22,500 lbs.

If a potato farmer gave his crop careful attention it would cost him $25 an acre to grow potatoes. What is the net profit an acre if the yield is 110 bu. worth 40 cts. a bu.? If the yield is 250 bu. worth 40 cts a bu.—Ans. $19.; $75.

How many acres of potatoes producing 90 bu. an acre must he grow to return as much net profit as 10 acres yielding 180 bu. an acre if the cost and price are the same as in the above problem? Ans.—42.7 A.

Five farmers sell a carload of 650 bu. of mixed potatoes at 42 cts. a bu. They divide equally. How much does each receive? Ans.—$54.40.

Five other farmers sell a carload of 650 bu. of uniform potatoes at 52 cts. a bu. Divide the returns among them equally. Ans.—$67.60.

Jack Smith and his brother Jim belong to a potato club. Jack spends an extra day selecting his seed from the field as they are dug for his acre of potatoes. Jim takes his seed at random and his crop yielded 98 bu. an acre while Jack's yielded 140 bu. an acre. How much did Jack make the day he selected his seed potatoes if potatoes are worth 50 cts. a bu.? Ans. $21.

The next season Jack not only chose his seed from the field as the potatoes were dug but noticing some scabby potatoes he bought a pint of formalin for 50 cts. which he mixed with 35 gals. of water. Just before cutting the potatoes for planting he soaked them in this solution for 2 hours and killed the scab. Jack raised 200 bu. an acre which he sold for 55 cents a bu. Jim raised 110 bu. which on account of scab sold for 40 cts. a bu. Find Jack's profits over Jim's. Ans.—$66.

F. E. Bugbee of Hastings, Fla., reports as follows on untiled land: Cost of raising crop $88.50 an acre, gross income $130 an acre. Find the net income on $12\frac{1}{2}$ acres. Ans.—$518.75.

Mr. Bugbee tile-drained a part of his land at a cost of $30 an acre. On this land the cost of raising a crop was $147.50 an acre and the gross income was $390 an acre. How many times did his clear profit on one acre pay for the tiling? Ans.—8 times.

In the Twin Falls country of Idaho the yield of potatoes is from 100 to 700 bu. per acre. The cost of producing a 150-bu. crop there is estimated at $44 an acre. At that rate what is the profit on 10 acres when potatoes sell at 50 cts. a bu.? Ans.—$310.

If by increasing the expense of the crop to $95 an acre a 600-bu. crop may be raised, what would be the net profit on 10 acres at 50 cents a bu.? Ans.—$2050.

POULTRY

If a flock of 80 hens average 90 eggs a year, what is the income from the flock with eggs at 20 cts. a dozen? Ans.—$120.

How many bushels of corn will it buy at 45 cts. a bu.? Of wheat at 70 cts.? Ans.—Corn, $266\frac{2}{3}$ bu.; wheat, $171\frac{3}{7}$ bu.

A flock of 200 hens average 90 eggs a year apiece. If the average price of eggs for the year is 20 cts. a dozen, what is the value of the flock's output? Ans.—$300.

If it takes 24 bu. of corn at 50 cts. a bu., 10 bu. of oats at 30 cts., and $15 worth of other feed to keep this flock for one year, what is the profit over the cost of the feed? Ans.—$270.

At 18 cts. a pound, what would be received from 60 hens weighing 7.5 lbs. each? Ans.—$81.

The market price of hens was 18 cts. a pound. What would be received from 60 hens each weighing 4.5 lbs. if the dealer docked them one cent a pound from the regular price because they were small and thin? Ans.—$45.90.

A farming community markets all their eggs together. If each farm produces 30 eggs a day how many farms will be needed to fill 7 cases each holding 30 dozen once a week? Ans.—12 farms.

What would be the gain per day on each farm if 5 cts. extra a doz. were secured by keeping the eggs clean and packing them neatly if it took a boy one hour each day whose services were worth 10 cts. an hour? Ans.—$1.40.

If a farmer's wife keeps 80 hens and each hen lays 125 eggs in a year, how much will her annual income be with eggs at 21 cts. a doz.? Ans.—$175.

If 12,000 lbs. of grain costing 1 cent a pound is required to feed the above flock a year and raise 300 young chickens, what will be her gain if the chicks are worth 35 cts. each and the eggs 21 cts. a dozen? Ans.—$160.

PROBLEMS WITH THE LEVER

The teeter-board is a kind of lever. The point of support is called the fulcrum. The teeter-board will balance when the weight on one end multiplied by its distance from the fulcrum equals the product of the weight on the other by its distance from the fulcrum.

John, who weighs 75 lbs., sits on one end of the teeter 6 ft. from the fulcrum, where must his brother Oscar sit if he weighs 60 lbs., to make the teeter-board balance?

Process: $75 \times 6 = 450$
$450 \div 60 = 7\frac{1}{2}$.—Oscar sits $7\frac{1}{2}$ ft. from fulcrum.

Cyrus, who weighs 120 lbs., sits on one end of a teeter 6 ft. from the fulcrum, how far from the fulcrum on the other end must his sister sit who weighs 90 lbs.? Ans.—8 ft.

John weighs 90 lbs., and his sister Jane 45 lbs. Both sit on one end of a teeter 8 ft. from the fulcrum. Victor weighs 120 lbs. How far from the fulcrum on the other end must he sit to balance John and Jane? Ans.—9 ft.

A man with a crowbar 6 ft. long places one end of it under a stone. He places the fulcrum, or rest, 1 ft. from the stone. If the man weighs 160 lbs., how heavy a stone can he raise with the crowbar? Ans.—800 lbs.

A man weighing 150 lbs. has a piece of timber 20 ft. long with which he wishes to raise the corner of a building. He places a fulcrum 6 in. from the building, how many pounds can he raise? Ans.—5850 lbs.

A doubletree is made for 2 horses of different weight. One end is 18 in. long and the horse pulls upon it with a force of 150 lbs. The other end of the doubletree is 20 in. long, how many pounds must that horse pull to keep even with the first? Ans.—135 lbs.

A doubletree is 4 ft. long. At what point must it be attached to a plow so that one horse will pull twice as much as the other? Ans.—16 in.; 32 in.

(Note.—What fraction of the load will each horse pull?)

At what point must the same doubletree be attached so that one horse will pull $1\frac{1}{4}$ times as much as the other? Ans.—$21\frac{1}{3}$ in.; $26\frac{2}{3}$ in.

(Note.—What fraction of the entire load does each horse pull?)

Two horses weigh 1600 lbs. and 1200 lbs. respectively. If each pulls $\frac{1}{10}$ of his own weight, how should a 4-ft. doubletree be attached so they will pull evenly? Ans.—$27\frac{3}{7}$ in. for the light horse; $20\frac{4}{7}$ in. for the heavy horse.

(Note.—Find what fraction of the load each horse pulls.)

ANIMAL POWER

The word "work" is used with different meanings. Men of science use it to mean motion against resistance. In this sense work is measured in foot-pounds. A boy pulling with a force of 2 pounds moves his little wagon 10 feet. The work done is 20 foot-pounds.

Process: $2 \times 10 = 20$ foot-pounds.

A man pushes a wheelbarrow with a force of 20 pounds long enough to move it 30 feet. The work done is 600 foot-pounds.

Process: $20 \times 30 = 600$ foot-pounds.

A horse pulling with a force of 150 pounds draws a load 10 rods. The work done is 24,750 foot-pounds.

Process: 10 rods = 165 feet.
$150 \times 165 = 24{,}750$ foot-pounds.

Rule.—Multiply the force in pounds by the distance in feet. The result is foot-pounds.

How much work is done when a 100-lb. boy climbs to the top of a 40-ft. windmill? Ans.—4000 foot-pounds.

How much work is done when a 60-lb. boy climbs a 9-ft. stairway? Ans.—540 foot-pounds.

How much work does a 1200-lb. horse do in walking up a 150-ft. hill? Ans.—18,000 foot-pounds.

(NOTE.—The force necessary to pull an object or tool is called the draft.)

The draft of a certain hand cart is 18 lbs. How much work does a man do in pushing it a mile? (5280 ft. in a mile.) Ans.—95,040 ft.-lbs.

How much work is done by a team in plowing a furrow 40 rods long when the draft of the plow is 450 lbs.? Ans.—297,000 ft.-lbs.

A horse does 290,400 ft.-lbs. of work in drawing a certain wagon one-half mile. What is the draft? Ans.—110 lbs.

What power is necessary to raise grain in an elevator to a height of 50 ft. at the rate of 990 bu. an hour? Ans.—49,500 ft.-lbs.

(NOTE.—There is always some power lost by contact of surfaces or friction.

In the foregoing problem what power will be required if 50% of it is lost in friction. Ans.—99,000 ft.-lbs.

If there could be such a thing as an absolutely smooth or frictionless horizontal surface a load moving along it would never stop, or in other words it would require no force to keep it going. But as there is always friction in some degree enough force must be used to overcome it if the load is to be kept in motion. By the use of wheels, lubricating oils, and hard road-beds, friction may be greatly reduced. The total force necessary to keep a ton moving on the best level macadam road may be as low as 30 to 50 lbs. On a hard, level earth road with an ordinary wagon the draft or traction is about 150 lbs. to the ton. A large draft horse may easily exert a force of 150 lbs. and keep this up working 10 hours a day walking at the rate of 2.5 miles per hour. This amount of work, 33,000 foot-pounds per minute, is called a horsepower.

If a horse is walking 2.5 miles an hour and pulling 150 lbs. on his traces, how much power is he developing? Ans.—1 horsepower.

PROCESS: $\frac{150 \times 5280 \times 2.5}{60} = 33{,}000$ ft.-lbs. a min. or 1 horsepower.

A horse is walking 2.5 miles per hour and pulling 100 lbs. on his traces. How much power is he developing? Ans.—$\frac{2}{3}$ horsepower.

Process: $\frac{100 \times 5280 \times 2.5}{33000 \times 60} = \frac{2}{3}$ horsepower.

(NOTE.—Use cancellation.)

How many horsepower is a horse developing when walking 5 miles an hour and pulling 60 lbs. on his traces? Ans.—$\frac{4}{5}$ horsepower.

How many horsepower is a team developing when walking 4 miles an hour and steadily pulling 165 lbs.? Ans.—1.7 horsepower.

If it requires a 1500-lb. draft horse walking at the rate of 2.5 mi. an hour to develop 1 horsepower, how much power may be exerted by a 1000-lb. horse walking at the same rate? Ans.—$\frac{2}{3}$ horsepower.

Careful tests have been made showing that a horse may be expected to pull about $\frac{1}{10}$ of its own weight and keep it up 10 hours a day walking 2.5 miles an hour. This pulling power is called traction.

If a horse can pull steadily with a force equal to $\frac{1}{10}$ of its own weight, what draft will a 1200-lb. horse exert? Ans.—120 lbs.

How much power will he develop walking 2.5 mi. an hour? Ans.—$\frac{8}{10}$ horsepower.

How much power may be expected from a 1500-lb. horse walking at the same rate? Ans.—1 horsepower.

At the same rate how much power may be expected from an 1800-lb. horse? Ans.—$1\frac{1}{5}$ horsepower.

What should be the pulling power of a two-horse team, one weighing 1600 lbs. and the other 1200 lbs. walking at the rate of 2.5 mi. per hour for 10 hours a day? Ans.—280 lbs.

How much horsepower is this team developing? Ans.—1.8 (plus) horsepower.

What should be the pulling power of a two-horse team, one weighing 1500 lbs. and the other 1400 lbs., walking at the rate of 2.5 mi. an hour for 10 hours? Ans.—$1\frac{14}{15}$ horsepower.

If a horse pulls $\frac{1}{10}$ of its own weight steadily for 10 hours a day walking 2.5 mi. an hour, how does a team of draft horses weighing 3200 lbs. compare with a light team, weighing 1800 lbs.; in horsepower? Ans.—$2\frac{2}{15}$ h. p.; $1\frac{1}{5}$ h. p.

COUNTING

12 things are one dozen (doz.).
12 dozen are 1 gross (gro.).
12 gross are 1 great gross (G. gro.).
20 things are 1 score.
24 sheets of paper are 1 quire.
20 quires or 480 sheets are 1 ream.

TIME MEASURE

60 seconds (sec.) are 1 minute (min.).
60 minutes are 1 hour (hr.).
24 hours are 1 day (da.).
7 days are 1 week (wk.).
2 weeks are 1 fortnight.
30 das. (31, 28, 29 das.) are 1 month (mo.).
3 months or 13 weeks are 1 quarter.
12 months or 365 days are 1 common year (yr.)
366 days are 1 leap year.
10 years are 1 decade.
100 years are one century (C.).

WEIGHTS OF PRODUCE IN A BUSHEL

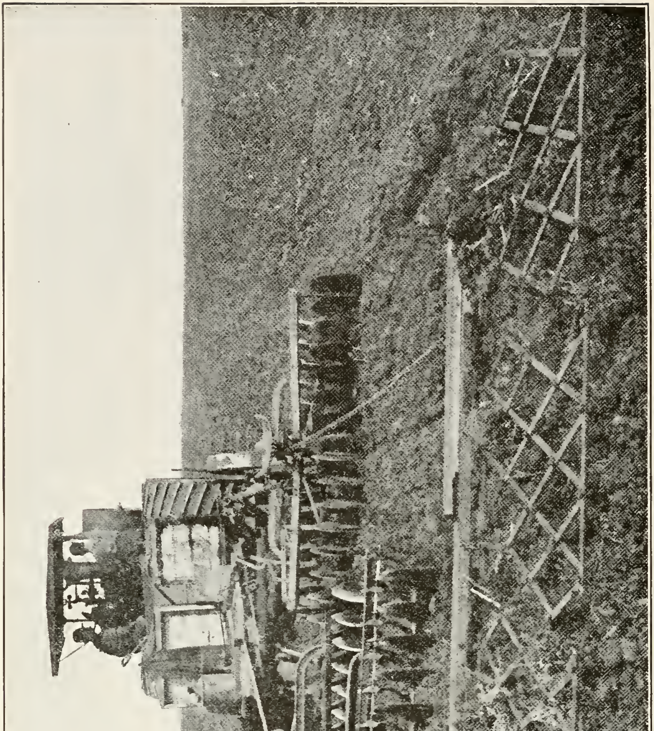
Wheat	60 lbs.
Corn in the ear	70 lbs., except in Miss., 72 lbs. in Ohio, 68 lbs. in Ind. after Dec. 1, and in Ky. after May 1 following the time of husking, it is 68 lbs.
Corn shelled	56 lbs., except in Cal., 54 lbs.
Rye	56 lbs., except in Cal., 54 lbs.; in La. 32 lbs.
Buckwheat	48 lbs., except in Cal., 40 lbs; Ky., 56 lbs.; Ida., N. D., Okl., Ore., S. D., Tex., Wash., 42 lbs.; Kan., Minn., N. C., N. J., Ohio., Tenn., 50 lbs.
Barley	48 lbs., except in Ore., 46 lbs.; Ala., Ga., Ky., Pa., 47 lbs.; Cal., 50 lbs; La., 32 lbs.
Oats	32 lbs., except in Ida. and Ore., 36 lbs.; in Md., 26 lbs.; in N. J. and Va., 30 lbs.
Peas	60 lbs.
White beans	60 lbs.
White potatoes	60 lbs., except in Md., Pa., Va., 56 lbs.
Sweet potatoes	55 lbs.
Onions	57 lbs.
Turnips	55 lbs.
Dried peaches	33 lbs.
Dried apples	26 lbs.
Clover seed	60 lbs., except in N. J., 64 lbs.
Flax seed	56 lbs.
Millet seed	50 lbs.
Hungarian grass seed	50 lbs.
Timothy seed	45 lbs., except in Ark., 60 lbs.; N. D., 42 lbs.
Blue grass seed	44 lbs.
Hemp seed	44 lbs.
Corn meal	50 lbs., except in Ala., Ark., Ga., Ill., Miss., N. C., Tenn., 48 lbs.
Bran	20 lbs.

HANDY VALUES

1 bu. = 2150.4 cu. in.
1 bu. = 1¼ cu. ft. (approximately), used for wheat, shelled corn and all small grains.
1 bu. corn on cob = 2½ cu. ft.
1 bu. corn in husk = 3¼ cu. ft.
1 heaped bu. = 2747.7 cu. in. (used for apples, potatoes, turnips).
1 heaped bu. = 1 5/9 cu. ft.
1 gal. = 231 cu. in.
1 gal. water = 8¼ lbs.
1 gal. average milk = 8½ lbs.
Milk averages 3.8% butter-fat.
1 lb. butter-fat = 1 1/6 lbs. butter.
1 bbl. = 4 cu. ft. (approximately).
1 bbl. = 31½ gals.
1 bbl. cement = 4 cu. ft.
1 bag or sack cement = ¼ bbl.
1 ton of well-packed timothy = 512 cu. ft.
1 ton of well-packed clover = 450 cu. ft.
1 cu. ft. water = 62½ lbs.
1 cu. ft. of ensilage = 30 lbs. (in small silo).
1 cu. ft. of ensilage = usual daily ration for a cow.
1 cu. ft. = 7½ gals. (approximately).
1 cord = 128 cu. ft.
1 ear of seed corn has about 800 kernels.
Corn shrinks 10% or more the first 6 months after husking.
1 roll of barbed wire weighs 100 lbs. approximately.
1 roll of barbed wire = 1200 ft. approximately.
1 mile = 5280 ft.

Grains and Vegetables	Average Quantity of Seed per Acre for Planting	Legal Weight per Bushel
Alfalfa	30 lbs.	60 lbs.
Barley	8 pks.	48 lbs.
Blue grass	20 lbs.	14 lbs.
Buckwheat	4 pks.	48 lbs.
Clover	12 lbs.	60 lbs.
Corn (in the husk)	......	72 lbs.
Corn, shelled, check row	7 qts.	56 lbs.
Corn, on cob	......	70 lbs.
Corn, ensilage	10 qts.	......
Cotton, upland	6 pks.	32 lbs.
Cowpea	6 pks.	60 lbs.
Oats	2½ bu.	32 lbs.
Potato	10 bu.	60 lbs.
Rye	6 pks.	56 lbs.
Timothy	15 lbs.	45 lbs.
Wheat	8 pks.	60 lbs.
Sweet potatoes	......	55 lbs.
Beans	......	60 lbs.
Peas	......	60 lbs.
Corn meal	......	48 lbs.
Bran	......	20 lbs.

(Legal weights vary in different states. See above. Extra fine wheat may weigh as much as 65 lbs. per bu Oats sometimes weigh 40 lbs per bushel.)



A PRIMITIVE INDUSTRY REVOLUTIONIZED BY MODERN POWER—PLOWING BY MACHINERY

FARM SCIENCE AND PRACTICE

There is widespread and growing demand for practical knowledge concerning scientific agriculture and country life. No subject now taught in the schools can be eliminated without serious objection, nor does there seem to be room for others to be crowded in. New subjects of agriculture and country life, therefore, must be acquired largely through the old subjects, re-cast and re-directed along agricultural lines so that the child in the country or in suburban districts may be taught in terms of his own environment. This is particularly true of the rural science and other practical subjects, a knowledge of which is in daily demand.

No subject is so well adapted to make clear the results of the best agricultural practices as arithmetic. It may be used to drive home the correct principles of farming and to nail them fast with figures. Moreover, no subject is more popular with boys and girls than arithmetic. It is, therefore, the best of all mediums through which to introduce scientific agriculture.

CHOOSING A FARM

WHAT *are the two points to consider in buying a farm?*

The economic, or money-making value, and the home value.

What is the home value?

A healthful location, near to schools, churches and desirable neighbors.

Which should be considered first, the home or economic value?

It depends whether one is to live on the farm or not.

Should a farmer invest all his capital in land?

It may be safe in a pioneer country where values are bound to rise but in older communities the higher the price of land the lesser part of one's capital should be invested in the bare land.

When should a farmer locate near a market?

If he intends producing cream, milk, fruit or even grain.

When can he afford to locate farther from a market or shipping point?

If he is a stock raiser, because they can be driven some distance.

Is it worth while to pay more for a farm near a transcontinental railroad?

Yes. It costs more to ship when two roads must be used to reach a large city market.

How far may milk and grain be hauled to market with profit?

Three miles is as far as a farmer can profitably haul his own milk, while five miles is a long haul for grains. Ten miles is not too far to market stock.

What relation do wagon roads bear to farming?

A farmer may travel two miles over a hard road with easy grades more easily and quickly than over one mile of hilly or muddy roads.

What other things should be considered in locating?

Electric lines add greatly to the value of a farm, also telephone lines. The occupation of the other farmers may help to advertise a section for fruit or fine stock and thus bring buyers that way.

For an investment which is better—a farm with no improvements or one with extensive improvements?

Better than either is a farm with moderate improvements just sufficient for the conduct of the farm.

What practice of farmers has contributed most toward exhausting the soil?

Raising the same crop on a given field for forty or fifty years without fertilizing or manuring or rotating.

ROTATION OF CROPS

Why should not the same crop be grown continuously on the same soil?

It will tend to exhaust certain plant foods needed by the crop because some crops make a special drain on one element of food.

How do plants differ in their manner of root growth?

Some plants, like wheat, are shallow-rooted and are surface feeders, while others extend their roots deeper.

Why is it wise to rotate deep and shallow rooted crops?

Because they feed at different depths and this plan will not exhaust the soil so quickly.

What other reason for this method?

The deep-rooted crops probably leave near the surface some food procured deeper in the soil.

What is the effect of shallow-rooted crops following deep-rooted crops?

They always prosper.

How does rotation affect the physical condition of the soil?

Different crops receive different cultivation and the shortcomings of one crop treatment is corrected by the preparation for the next crop and thus the soil is kept in better condition.

Does the different manner of rooting affect the soil?

It is well to have the roots of stubble, clover and grasses periodically left in the soil to decay to improve the texture of the soil.

What effect has rotation on the farmer's labor?

Rotation distributes the care of crops throughout the season and thus economizes labor, and enables the farmer to keep regular help which is better than transient help.

Does rotation affect plant diseases?

Most plant diseases are fungi or bacteria that live in only one kind of plant. Therefore rotation starves them out.

What effect has rotation on insects?

Most insects have their favorite crops and as many of them live only a few years they, too, are starved out by rotation.

How does rotation affect weeds?

Crops are cultivated differently and harvested in different manners and at different times and this tends to drive out weeds by striking them at their weak points.

If land is badly infested with a certain weed how can it be freed from it?

By leaving out of the rotation the particular crop whose cultivation offers aid to the weed.

What effect has rotation on the size of the crop?

Experiments show much better crop yields where rotation is practiced.

Can any general rules be given for rotation?

Every rotation should include at least one hoed or cultivated crop such as corn and potatoes and one legume such as clover.

Why is the hoed crop desirable?

It destroys weeds and improves tilth.

Why the leguminous crop?

Because legumes are deep-rooted and get food from the subsoil; they increase the nitrogen supply in the soil and leave it porous.

Give a general rule for rotation.

The crops should vary as much as possible in food requirements, manner of growth, root system, and in the season during which they occupy the ground.

PRESERVING FOODS

What causes canned goods to spoil?

The presence of any one of three living organisms will cause decay of vegetable or animal matter—they are yeast, molds, and bacteria.

What conditions aid the growth of yeast plants?

They need warmth, moisture, sugar.

How does the yeast plant grow?

By budding, that is, the parent

plant divides into two plants and these grow and divide, and the process continues as long as conditions are favorable.

Where will yeast grow most easily?

In fruit juice and slightly sweetened fruit, but not in thick sirups or preserves. It is easily killed by a high or low temperature.

How does mold get a start?

The spores or seeds of mold are very light and may be floating in the air. When they lodge on a warm, moist surface such as food often presents, they germinate and cover the surface.

How may molds be destroyed?

By exposure to a high temperature for about twenty minutes.

Where do bacteria grow?

Bacteria multiply rapidly in meat, milk, and legumes, but will not grow in thick sirups or acids.

What makes fruit juices form jelly?

A carbohydrate resembling starch called pectin is an important factor in the juice of ripe or nearly ripe fruit. When equal amounts of sugar and fruit juice are mixed and heated this pectin causes the mixture to gelatinize or form jelly.

What are the essentials in canning and preserving?

Cleanliness and sterilization.

How shall we sterilize?

By scalding or boiling all kettles, jars, strainers, rubbers and other utensils used in canning.

Give general rules for canning foods.

Kill all germs in the food and inside the cans and seal while hot so as to prevent other germs from the air to enter.

How does the drying of fruits and meats preserve them?

Germs or bacteria cannot grow without the presence of water.

Why does salting meat preserve it?

Because bacteria cannot live in a strong solution of common salt.

Does putting fruit and meat in cold storage kill the bacteria?

A low temperature simply keeps them from growing and multiplying. They begin to act as soon as the temperature rises.

How does smoking meat preserve it?

Smoking coats the outside of the meat with a thin layer of creosote which not only kills all germs present but gives the meat a different flavor.

What effect has sugar on keeping qualities?

Sugar is a preservative against the action of germs. It is used in curing meats and extensively in preserving fruit.

Why does preserving keep fruit?

"Boiling down" for a long time kills the germs and drives off the water, making conditions unfavorable to growth.

What makes milk sour?

Germs or bacteria.

Where do they come from?

The air is full of germs, the dust from the barn is laden with them and they are on the milk pail and the hands of the milker.

How should we care for milk cans and pails?

They should all be thoroughly washed and scalded and placed in the sunlight which is an enemy to germs.

What causes butter to become rancid and how prevented?

Bacteria. It is best overcome by working out all the water which bacteria need and mixing in salt.

What makes cider turn to vinegar?

The solid slimy mass known as mother of vinegar is a vast colony of bacteria. It is the action of these that causes the change.

Where do the vinegar-making bacteria come from?

From the air and from the barrel. The process may be hastened by introducing "mother of vinegar."

PLANT LIFE IN THE GARDEN, ORCHARD, VINEYARD AND GREENHOUSE

What are the parts of a plant?

There are five: root, stem, leaf, flower and seed.

What are the uses of the root?

The roots hold the plant in place and prevent its blowing away, they take nourishment and moisture from the soil; and serve as storage places for plant food.

What is a root cap?

The tip of the tender root has a little cap on the end to enable it to force its way among the soil particles without injury.

What are root hairs?

They are a hair-like, velvety growth covering the real roots.

What is the use of root hairs?

The root hairs present a much greater surface through which the plant may absorb food and moisture.

Do the real or fibrous roots absorb food and moisture?

No, this is the work of the root hairs, which cover the fibrous roots.

How do the root hairs take their food?

Their walls are very thin and the plant food in order to enter must be in a soluble or watery form which will pass through these thin walls.

What is this passing of liquids through the thin partitions of the membranes called?

It is called *osmosis.* It is the same process as that by which the food passes from the alimentary canal of animals into the blood.

What are the uses of plant stems?

They support the leaves and hold them up in the air and sunlight. They serve as storehouses for starch and sugar and other forms of plant food for the future use of plants. The stems are also channels for the passage of sap through the plant.

What is the use of the sap?

It carries raw plant food from roots to leaves and then carries the manufactured food like starch and sugar to the place where it is needed to build up the plant or to the place of storage.

What uses have leaves?

The leaves give off water to the air, take carbon from the air, and change raw plant food to starch and sugar. They are the food factory of the plant.

In what form does carbon exist in the air?

The air contains carbonic acid gas which is composed of oxygen and carbon. It is sometimes called carbon dioxide.

From what does the air obtain carbonic acid gas?

It is exhaled or breathed off by all animal life. It is also given off by decaying plant life.

How does the leaf get hold of carbonic-acid gas?

The air may enter the leaf through openings on the under side called *stomata* which means "mouths."

How does the leaf separate the carbonic-acid gas into oxygen and carbon?

The heat furnished by sunlight and the green coloring matter of leaves called chlorophyll act together and separate the oxygen from the carbon.

What becomes of the oxygen? and carbon?

The oxygen is given off to the air and the carbon is combined with other food elements to make such compounds as starch and sugar which are then ready to build up the plant.

What is the use of chlorophyll?

Only the plants that have the green chlorophyll are able to use carbon dioxide from the air to manufacture starch and sugar.

What about the plants that grow in the dark?

Mushrooms grow in dark places and can get no food from the air because they have no green chlorophyll. Their food comes from partly decomposed matter in the soil.

What is meant by the balance in nature?

Animals need large quantities of oxygen which plants give off while plants need large amounts of carbon dioxide which animals give off. What is poison or waste of animals is food for plants, and the reverse is also true.

What things besides plant food are needed for plants?

Plants need light, heat, moisture, and air.

What is the main aim of life for all plants?

To produce seed.

What part of the plant bears the seed?

The flower.

What parts has a perfect flower?

Pistils and stamens.

What is the office of the stamens?

Stamens are the male part of the flower. They bear the yellow dust or pollen which is needed to fertilize the pistil or female part to enable it to produce seed.

What are imperfect flowers?

When the flowers of a plant do not contain both male and female parts they are known as imperfect flowers.

How do imperfect flowers bear seed?

The pollen must be carried to the flowers having the pistils by some means.

How is it carried?

The pollen of corn, which is light, is carried by the wind. In some cases it is carried by insects, such as bees.

What is cross-pollination?

Plants are cross-pollinated when the pollen is taken from one to another by some means. Some varieties of apples, pears, peaches and plums will not bear fruit if grown by themselves, but will bear abundantly if pollinated by other varieties that blossom at the same time.

Describe a seed.

A seed bears within its coat a minute plant called a germ.

What is the purpose of this germ or tiny plant?

To develop into a new plant like the parent when proper conditions are offered.

How can the seeds begin to grow with no leaves in the air and no roots in the ground?

Some nourishment prepared by the parent plant is stored up in the seed to feed it until it can put forth leaves and roots of its own.

Where is this store of nourishment?

In the bean it is in the two seed leaves. In the corn kernel a store of starch is found about the germ.

What part of the stem carries the water from the roots to the leaves?

In plants with netted veins in the leaves the water passes up mainly through the ducts or channels in the outer wood.

How are plants classified?

They may be classified in different ways. According to length of life as annuals, biennials, and perennials.

What are annuals?

Annuals are plants that live only one year from the planting of the seed to the production of the new seed, such as oats, peas, beans and tomatoes.

What are biennials?

Biennials live two years from seed to seed, such as cabbages, parsnips and common mullein.

What are perennials?

Perennials live more than two years, such as asparagus, alfalfa, strawberries and trees.

How do we know that different plants take different amounts of plant foods from the soil?

Chemists have analyzed various plants and thus ascertained what elements they contain and in what proportion.

How many elements in the soil?

Between seventy and eighty are known.

Why are they called elements?

Because scientists have not been able to separate them into similar substances.

Are most materials that we know simple elements?

Most materials are compounds, that is, they are combinations of two or more elements combined in different proportions.

What are some compounds that make different articles because the proportion of their elements differ?

Alcohol, sugar, starch, and fats all contain the same elements, carbon, hydrogen, and oxygen, but in different proportions.

Are there many compounds in a single plant?

Yes, but they may be separated and known.

What proportion of corn plant is water?

One thousand pounds of mature corn contains nearly 800 pounds water, 12.7 pounds hydrogen, and 88.9 pounds oxygen, and since both hydrogen and oxygen come from water nearly 900 pounds of the 1000, or nine-tenths of the corn plant, is water.

Is this nine-tenths of the plant's weight all the water it needs to grow?

It is only a small part, for the leaves are constantly giving off moisture to the air, and it is from this moisture that the plant obtains mineral foods.

How many pounds of water does the plant use for every pound of dry matter?

About 300 pounds of water passes through the plant for each pound of dry matter produced.

About how much water is needed by an acre of good corn during the growing period?

About 900 tons, an amount if spread over the acre would be nearly 8 inches deep.

Does this include the water lost from the land by drainage?

No, about as much water runs away and passes down beyond the reach of the roots of the corn as is used by the crop, so that about 1800 tons of water should fall upon an acre of growing corn.

How does the plant obtain moisture?

It all comes from the ground through the roots.

In what other way is water useful to plant life?

Besides furnishing about nine-tenths of the plant's weight, it dissolves other plant foods in the soil and puts them in shape to be taken up in a liquid form by the roots.

What makes a plant wilt on a very hot day?

Because the leaves are giving off moisture to the air faster than the roots can supply it to the plant.

Is there any other factor so important to plant life as proper moisture?

No. More soils fail to produce good crops for lack of proper moisture than for any other cause.

Do plants get any food from the air?

Nearly half of the dry matter in the plant consists of carbon, all of which comes from the air in the form of carbonic-acid gas.

Is carbonic-acid gas pure carbon?

It is a compound of carbon and oxygen, but the plants separate these elements, retain the carbon and set the oxygen free.

How is this done?

The green coloring matter of the leaves or the chlorophyll with the help of the heat energy furnished by the sunlight breaks apart the carbon and oxygen.

Is sunlight necessary to this process?

Plants grow more vigorously in full sunlight than in shade, and at night this growing process ceases.

Will not plants germinate in the dark?

They grow until they use up the food stored in the seed, but they have no power to use the food in the air and soil without chlorophyll and sunlight. Analysis shows that the plant grown in the dark contains less dry matter whan was present in the seed.

How does the plant use carbon?

It causes the carbon to combine with water and mineral matter which are taken through the roots, and these elements form carbohydrates of which the plant is composed.

Is it necessary for the farmer to buy carbon to fertilize his soil?

The atmosphere furnishes free an inexhaustible supply of carbon for all vegetation.

What is the most costly plant food?

Nitrogen.

Do plants contain a high percentage of nitrogen?

Nitrogen forms only from one to three per cent of the dry matter or about one-half of one per cent of the green plant. But a crop must have this proportion in order to thrive.

Where do plants get their supply of nitrogen?

From the soil only.

Where does the soil get nitrogen for the growing crops?

A small part comes directly from the atmosphere, brought by rain water. But most of the nitrogen is taken from the air and stored in the soil by bacteria that live in small swellings or nodules on the roots of certain plants called legumes, such as clover, alfalfa, soy bean, cowpea, and the like.

How can the farmer help these bacteria?

By stirring the soil so the air can enter it, for bacteria cannot live without oxygen from the air.

What part of the green plant comes from the air?

Including water, ninety-eight and one-half per cent comes from the air free of cost and the supply of these elements of food in the air is beyond control.

Are there many elements of food in the other one and one-half per cent of green plants?

There are about a dozen, but the three demanding the farmer's attention are nitrogen, phosphoric acid and potash. The other elements are generally found in the soil in abundance except occasionally lime is missing.

STOCK FEEDING

Foods may be said to serve two purposes. They either build up the body or furnish heat and energy. They are divided into three classes: proteins, carbohydrates, and fat.

Protein is a name given to a group of feeds or compounds from which animals make muscle or lean flesh, bone, hair or wool, tendons, nerve, casein, and albumen in milk, etc. Since no other compound can take the place of protein it is important that enough of this be fed or the animal cannot keep up in flesh and production or work. If too much protein is fed it will replace the other food elements, but as feeds containing a high percentage of protein are usually expensive it is unwise to feed more of it than is needed. Feeds containing a large proportion of protein, such as clover, bran, and oil meal, are called nitrogenous foods.

Carbohydrates (C. H.) are those compounds in feed that are composed of carbon, hydrogen and oxygen, but have no nitrogen. Sugar, starch, fiber and others are carbohydrates. They are used in the body to produce fat or are burned to produce heat or energy. They cannot take the place of protein.

Fat. The oils, wax and fats contained in feed are called fats. In the animal body they are used for the same purpose as are carbohydrates. One pound of fat is equal to 2¼ pounds of carbohydrates.

The work horse and cow of average size require daily about two pounds of protein and twelve pounds of carbohydrates.

If a farmer intends to feed his animals without waste he must give them protein and heat and fat producing elements (which latter includes C. H. and fats) in certain proportions. It may be 1 : 6 or 1 : 11 or some other proportion. This correct proportion is called a balanced ration which is indicated by figures called a nutritive ratio.

The following table gives the digestible protein and carbohydrates contained in certain feeds. The fats are included with the carbohydrates.

	Estimated Price	IN 100 LBS. OF FEED			
		Protein	Protein	Carbohydrates (Including Fats)	
		lbs.	per cent	lbs.	per cent
Corn fodder	$3 per T	2.5	2.5%	37.3	37.3%
Timothy hay	$12 per T	2.8	2.8%	46.6	46.6%
Clover hay	$12 per T	6.8	6.8%	39.6	39.6%
Cowpea hay	$12 per T	10.5	10.5%	40.	40%
Alfalfa hay	$12 per T	11.	11%	42.4	42.4%
Oat straw		1.2	1.2%	40.4	40.4%
Wheat straw		.4	.4%	37.2	37.2%
Wheat bran	$18 per T	12.2	12.2%	45.3	45.3%
Corn	49 cts. per bu	7.9	7.9%	76.4	76.4%
Oats	37 cts. per bu	9.2	9.2%	56.8	56.8%
Cotton seed meal	$30 per T	37.2	37.2%	44.4	44.4%
Corn stover	$5 per T	1.7	1.7%	34.	34%
Corn silage	$3 per T	.9	.9%	12.9	12.9%
Skim milk	20 cts. per cwt	2.9	2.9%	5.9	5.9%

DIGESTIBLE NUTRIENTS IN 100 POUNDS OF VARIOUS FEEDING STUFFS

	Total Dry Matter	POUNDS AND PER CENTS OF DIGESTIBLE NUTRIENTS				Nutritive Ratio
		Protein		C. H. and Fat ×2.25		
	lbs. or %	lbs.	%	lbs.	%	
Alfalfa hay	91.6	11.	11.	42.3	42.3	1: 3.8
Apples	19.0	.7	.7	18.8	18.8	1:26.8
Barley, grain	89.1	8.7	8.7	69.1	69.1	1: 7.9
Beet, mangel	9.1	1.1	1.1	5.6	5.6	1: 5.1
Cabbage	15.3	1.8	1.8	9.1	9.1	1: 5.1
Carrot	11.4	.8	.8	8.3	8.3	1:10.4
Clover, red (green)	29.2	2.9	2.9	16.4	16.4	1: 5.7
Clover, red (hay)	84.7	6.8	6.8	39.6	39.6	1: 5.8
Corn fodder, dry	57.8	2.5	2.5	37.3	37.3	1:14.9
Corn, grain	89.1	7.9	7.9	76.4	76.4	1: 9.7
Corn silage	20.9	.9	.9	12.9	12.9	1:14.3
Corn stover	59.5	1.7	1.7	34.0	34.	1:20
Cottonseed meal	91.8	37.2	37.2	44.4	44.4	1: 1.2
Cowpea hay	89.3	10.8	10.8	40.	40.	1: 3.9
Linseed meal	89.	28.2	28.2	47.	47.	
Meat scrap	89.3	66.2	66.2	31.1	31.1	1: 0.5
Milk, cows'	12.8	3.6	3.6	13.2	13.2	1: 3.7
Skim milk (separator)	9.4	2.9	2.9	5.9	5.9	1: 2.
Buttermilk	9.9	3.9	3.9	6.5	6.5	1: 1.7
Hay (mixed grasses)	87.1	5.9	5.9	43.6	43.6	1: 7.4
Oat straw	90.8	1.2	1.2	40.4	40.4	1:33.7
Oats, grain	89.	9.2	9.2	56.8	56.8	1: 6.2
Potatoes	21.1	.9	.9	16.5	16.5	1:18.3
Pumpkin, field	19.1	1.4	1.4	6.5	6.5	1: 4.6
Rye, grain	88.4	9.9	9.9	70.1	70.1	1: 7.1
Rye bran	88.4	11.5	11.5	54.8	54.8	1: 4.8
Rye straw	92.9	.6	.6	41.5	41.5	1:69.2
Soy-bean	89.2	29.6	29.6	54.7	54.7	1: 1 8
Timothy hay	86.8	2.8	2.8	46.6	46.6	1:16 6
Turnip, flat	9.5	1.0	1.0	7.7	7.7	1: 7.7
Wheat, grain	89.5	10.2	10.2	73.	73.	1: 7.2
Wheat bran	88.1	12.2	12.2	45.3	45.3	1: 3.7
Wheat middlings	87.9	12.8	12.8	60.7	60.7	1: 4.7
Wheat straw	90.4	.4	.4	37.2	37.2	1:93.

Some animals require one ratio and other animals a different ratio depending upon whether the animal is young and growing or mature, whether it is at work or at rest. Ratios are said to be wide or medium or narrow. Timothy hay (1 : 16.6) is wide; alfalfa (1 : 3.8) is a narrow ratio.

Finding the ratio

The nutritive ratio is found by dividing the pounds of protein in a feed or ration, into the pounds of C. H. (including the fats). This may be more easily understood by putting these amounts in the form of a fraction, in which the protein is the numerator and the C. H. including fats is the denominator. Thus the nutritive ratio of

Alfalfa $= \frac{11}{42.3}$ (See table Page 257)

Divide both terms of the fraction by the numerator

$$\frac{11}{42.3} \div \frac{11}{11} = \frac{1}{3.8}$$

$\frac{1}{3.8}$ is the same as 1:3.8

Feeding standards

Different animals require different quantities of feed and different nutritive ratios. A dairy cow producing milk must have a feed rich in protein, a dry cow does not require so much protein. A horse at heavy work requires a different feed from that of one at rest; a growing pig from a mature hog that is being fattened for market.

The following table shows the amounts of digestible nutrients per day in feeding standards upon the basis of 1000 pounds of live weight.

FEEDING RATIONS PER DAY FOR 1000 LBS. OF LIVE WEIGHT

	Dry Matter	Digestible		Nutritive Ratio
		Protein	C. H. including Fats (×2¼)	
Oxen at rest in stall	18 lbs.	0.7 lbs.	8.2 lbs.	1:11.8
Growing pigs	36 lbs.	4.5 lbs.	26.6 lbs.	
Fattening swine	32 lbs.	4 lbs.	25.1 lbs.	
Growing calves	30 lbs.	2.5 lbs.	16.1 lbs.	
Fattening cattle	30 lbs.	3 lbs.	16.1 lbs.	
Horse (light work)	20 lbs.	1.5 lbs.	10.4 lbs.	
Horse (heavy work)	26 lbs.	2.5 lbs.	15.1 lbs.	
Dairy cow (giving 11 lbs. milk daily)	25 lbs.	1.6 lbs.	10.7 lbs.	
Dairy cow (giving 16.5 lbs. milk daily)	27 lbs.	2 lbs.	11.9 lbs.	
Dairy cow (giving 22 lbs. of milk daily)	29 lbs.	2.5 lbs.	14.1 lbs.	
Dairy cow (27.5 lbs.)	32 lbs.	3.3 lbs.	14.8 lbs.	
Wool sheep (coarse breed)	20 lbs.	1.2 lbs.	11 lbs.	
Wool sheep (fine breeds)	23 lbs.	1.5 lbs.	12.7 lbs.	

Bran alone does not make a balanced ration for a cow because if a sufficient amount of bran is fed to furnish two pounds of protein the cow does not get enough C. H. If enough is fed to furnish the correct amount of C. H., then she is given more protein than she can use, and it is wasted. Bran is not only too expensive but too concentrated and should be fed sparingly. Hay, fodder, silage and the like will give the proper bulk for a ration and furnish cheaper food.

Since protein is the element of food most commonly lacking in feed rations on the farm, every feeder should make sure that he is providing enough protein. The cheapest way to provide protein is to raise a legume such as clover, alfalfa, or cowpea hay which is very rich in protein.

If a farmer must buy protein it is best to estimate its cost according to the percentage as given on page 258 and the market price. In the foregoing problems it is figured on an average market price. It must be remembered that it does not cost a farmer $12 a ton to raise clover, cowpea, or alfalfa hay, but more nearly $4 a ton.

Heat value of fats

By careful test it has been shown that one pound of fat will produce 2¼ times as much heat or energy as one pound of carbohydrates.* In the table on page 258 the fats are included in the C. H. Many tables give them separately and the farmer or pupil should know how to deal with such tables.

Dry matter

The mature student will take note that the bulk of the ration—that is, the pounds of dry matter in each ration—has been omitted for the sake of making the problems simple. In compounding the ration the dry matter is important. The dry matter in each ration may easily be computed from the percentage given in column 1, page 258. The amount of dry matter may vary two or three pounds from the exact amounts called for on page 258 without much consequence.

Mixing a Ration

It is not necessary to weigh a ration each day. Mix the grain ration in proper proportions and use a measure that contains the right amount for each animal. Weigh the hay once or twice and thereafter it can be estimated with sufficient accuracy.

Each pupil should try to make a ration for a 1000-pound cow giving 16½ pounds milk, using such feeds as are commonly used on your farm. You will have to make several trials perhaps before you get the right amounts. Remember that if your ratio is too wide it needs more protein and therefore use more clover, alfalfa or cowpea hay or if your feed is already too bulky, that is, if it already has too much dry matter, then use bran or linseed meal or cottonseed meal, or some concentrated food to reduce the ratio to suit your animal. The dry matter should be within a few pounds of the amount required in table, page 258. The amount of dry matter is found by using the percentages given in column 1, page 258.

*To reduce fats to C. H. Rule: Multiply the fats by 2¼ and add the product to the C. H.

FERTILIZERS

James J. Hill tested 151 farms in the northwest for wheat, barley and oats. By applying 8.9 pounds of nitrogen, 47 pounds of phosphoric acid and 130 pounds of potash an acre the wheat on 51 farms increased 11.4 bushels an acre.

The composition of fertilizers varies to some extent, but the following is a fair average.

A complete fertilizer is one that contains all three of the ingredients—phosphoric acid, nitrogen, and potash. Since a crop of clover or other legumes may furnish all the needed nitrogen it is often unnecessary and expensive to buy a complete fertilizer. In such a case all that is needed is the phosphoric acid and the potash.

It is usually cheaper and more satisfactory for the farmer to buy the ingredients and mix them on the farm.

The following table shows the amount of nitrogen, phosphoric acid and potash removed from the soil by various crops.

	Amount	Nitrogen	Phosphoric Acid	Potash
		lbs.	lbs.	lbs.
Corn, grain	100 bu.	100	17	19
Corn stover	3 T.	48	6	52
Oats, grain	100 bu.	66	11	16
Oat straw	2½ T.	31	5	52
Wheat, grain	50 bu.	71	12	13
Wheat straw	2½ T.	25	4	35
Timothy hay	3 T.	72	9	71
Clover seed	4 bu.	7	2	3
Clover hay	4 T.	160	20	120
Cowpea hay	3 T.	130	14	98
Alfalfa hay	8 T.	400	36	192
Apples	600 bu.	47	5	57
Apple leaves	4 T.	59	7	47
Apple wood growth	1/50 tree	6	2	5
Potatoes	300 bu.	63	13	90
Sugar beets	20 T.	100	18	157
Fat cattle	1000 lbs.	25	7	1
Fat hogs	1000 lbs.	18	3	1
Milk	10,000 lbs.	57	7	12
Butter	500 lbs.	1	0.2	0.1
Cotton lint	500 lbs.	1.7	.5	2.3

Commercial fertilizers are bought and used for the phosphoric acid (P. A.), nitrogen (N.) and potash (P.) they contain. These elements are obtained from different substances. Some substances contain one, some two, and some all of these plant foods. Fertilizers are labeled according to the per cent of phosphoric acid, nitrogen and potash they contain. An 8-2-4 fertilizer contains 8 per cent phosphoric acid, 2 per cent nitrogen, and 4 per cent potash. (In some states the order is reversed—nitrogen, phosphoric acid and potash, and the above formula would be 2-8-4.)

The prices of fertilizing materials are subject to market changes, but are usually about as follows:

Nitrate of soda 3 cts. per lb. in 200 lb. bags
Muriate of potash 3 cts. per lb. in 200 lb. bags
Acid phosphate 1 ct. per lb. in 125 lb. bags

FERTILIZING SUBSTANCES AND THE ELEMENTS THEY CONTAIN

	Phosphoric Acid	Nitrogen	Potash
Acid phosphate	14%	......	......
Ground phosphate rock	32%	......	......
Tobacco stems	2%	1.5%	5%
Sulphate of potash (high grade)	....	......	50%
Muriate of potash	....	......	50%
Nitrate of potash	....	13%	45%
Kainit	....	......	12.5%
Wood ashes (unleached)	1.5%	......	6%
Cottonseed meal	2.8%	6.2%	1.8%
Cottonseed	1.3%	3%	1.2%
Tankage (concentrated)	1.5%	12%	......
Dried blood (high grade)	....	14%	......
Fish scrap	7%	9%	......
Nitrate of soda	....	15.8%	......
Sulphate of ammonia	....	20.5%	......
Ammonia	....	82.4%	......

PROBLEMS IN CONNECTION WITH FERTILIZERS

If nitrogen is worth 18 cents a pound, phosphoric acid 6 cents, and potash 5 cents, find the value of these fertilizers in each of the following problems:

In 100 bu. of corn and 3 tons of corn stover. Ans.—$31.57.

In 100 bu. of oats and 2½ tons of oat straw. Ans.—$21.82.

In 50 bu. of wheat and 2½ tons of wheat straw. Ans.—$20.64.

In 3 tons of timothy hay. Ans.—$17.05.

In 4 bu. of clover seed and 4 tons of clover hay. Ans.—$37.53.

Compare 3 tons of cowpea hay with8 tons of alfalfa hay. Ans.—Cowpea, $29.14; alfalfa, $83.76.

Compare the ravages from the soil of a crop of 300 bu. of potatoes with a crop of 20 tons of sugar beets. Ans.—Potatoes, $16.62; beets, $26.93.

Compare the cost of fertilizer elements used in producing 1000 lbs. of fat cattle with that of 1000 lbs. of fat hogs. Ans.—Cattle, $5.27; hogs, $3.47.

What is the value of the fertilizers used from the soil in producing 10,000 lbs. of milk and 500 lbs. of butter? Ans.—$11.44.

A corn crop of 80 bu. to the acre takes 146 lbs. of nitrogen, 57 lbs. of phosphoric acid and 82 lbs. of potash from each acre of land. With nitrogen worth 20 cts. a lb., phosphoric acid, 5 cts. a lb. and potash 5 cts. a lb., what is the value of the plant food removed by the corn crop? Ans.—$36.15.

A farm raises and ships away 400 bu. of wheat. With fertilizer at the same price as in the above problem, what is the value of the plant food removed? Ans.—$123.60.

Compare the value of plant food (nitrogen, phosphoric acid, and potash) removed by 500 bu. of wheat and 500 bu. of potatoes. Ans.—Wheat, $154.50; potatoes, $29.60.

What is the value of the plant food removed from a 20-acre field of oats yielding 50 bu. to the acre? Ans.—$145.50.

The barley increased 16.4 bu. per acre. At this rate find the increased profit on 40 acres with barley at 60 cents a bu. and fertilizer $2 an acre. Ans.—$313.60.

CONCRETE CONSTRUCTION

Concrete is a mixture of gravel or crushed stone, sand, and Portland cement. Concrete is used for the building of foundations, steps, sidewalks, cellars, and farm building floors, cisterns, watering and feeding troughs, fence and hitching posts, culverts, building blocks, etc.

The crushed stone and sand should be reasonably free from clay or loam and the sand should not be too fine. Walks and floors should be underdrained and should have a slope of 1 inch in 4 feet for surface drainage. Where freezing occurs walks may be underlaid with from 4 inches to 12 inches of cinders, gravel, or broken stone well wetted and very well stamped into place. Foundations and piers should extend below the frost line.

Concrete Formula

A formula is used to show the proportional amounts by volume of each of the three ingredients of concrete. A 1-2-4 concrete is composed of 1 part cement, 2 parts sand and 4 parts gravel or crushed stone.

DIFFERENT FORMULAS			AMOUNTS NEEDED FOR 1 CU. YD. CONCRETE		
Cement	Sand	Stone or Gravel	Cement, bbls.	Sand, Cu. Yd.	Stone, Cu. Yd.
1	1	...	4.8		
1	1.5	...	3.87	..	..
1	2	...	3.21	..	..
1	2.5	...	2.74	..	
1	1.5	2	2.30	..	..
1	1.5	2.5	2.09	..	..
1	1.5	3	1.91	..	..
1	2	3	1.74	..	..
1	2	4	1.51	..	..
1	2.5	5	1.24	..	.
1	3	5	1.16	..	..
1	3	6	1.06	..	..

This formula is richer in cement than is ordinarily required. For walks, cellar floors, building walls, etc., a 1-2½-5 mixture is sufficient. For heavier work the proportion may be 1-3-6.

Mixing directions

Spread out the measured quantity of dry sand on a level, water-tight platform. On top of this spread the cement and turn dry with shovel until thoroughly mixed — at least three times. Then add the gravel or crushed stone. Wet thoroughly and turn again—at least three times, adding the water slowly from a sprinkler so as to make a thick mush.

For the upper course on sidewalks and floors only cement and sand are used. Since there is a space between the pieces of crushed stone or gravel it can easily be seen that a considerable volume of cement or gravel may be added to a given quantity of crushed stone without increasing the volume.

It is usually estimated that the given volume to be filled with the mixture must be increased 45 per cent in calculating the amount of materials needed. This is called 45-per-cent voids, or openings in the stone. If one had a space of 100 cubic feet to be filled with concrete, it would be necessary to order 145 cubic feet of the three ingredients.

Sand and stone are bought by the cubic yard and cement by the sack or barrel. A sack of cement is one-fourth of a barrel and weighs about 100 pounds. A barrel is estimated to contain 4 cubic feet.

PRACTICAL PROBLEMS INVOLVING CEMENT

How many cu. yds. of concrete are required in the construction of a cellar floor 14 ft. by 24 ft. and 4 in. thick? Ans.—$4\frac{4}{27}$ cu. yds.

How many cu. yds. would be required for two 3-in. floors, one 10 ft. by 12 ft., and the other 16 ft. by 30 ft.? Ans.—$5\frac{5}{9}$ cu. yds.

Find the number of cu. yds. of cinders required to make a 12-in. foundation for a walk to the barn 162 ft. long, $2\frac{1}{2}$ ft. wide and 4 in. thick. Ans.—5 cu. yds.

Estimate the amount of concrete needed to build a feeding trough with walls 4 in. thick and inside measurements 10 ft. long by 18 in. wide and 10 in. deep. Ans.—14 (plus) cu. ft.

How much concrete is needed to build the walls and floor of a cellar 10 ft. by 12 ft. and 8 ft. high inside measurements, if the side walls are 8 in. thick and the floor 4 in. thick? Ans.—15 cu. yds.

Estimate concrete needed to build a circular silo 20 ft. in diameter and 32 ft. high, with 12-in. walls and 8-in. floors. Ans.—82 (plus) cu. yds.

What quantity of each material will be required in a 1-2-4 mixture for a walk to the barn 108 yds. long, $2\frac{1}{2}$ ft. wide and 4 in. thick? Ans.—15.1 bbls. cement; 4.48 cu. yds. sand; 8.96 cu. yds. stone.

How many sacks of cement will be required to make 4.5 cu. yds. of a 1-2-4 mixture, also how much sand and gravel or stone? Ans.—27.2 sacks or 6.8 bbls. of cement; 2.02 cu. yds of sand; 4.03 cu. yds of stone

What would be the cost of the concrete in a walk 108 yds. long, $2\frac{1}{2}$ ft. wide, and 4 in. thick, with cement costing $1.35 a bbl., sand 75 cts. a cu. yd., and crushed stone $1.25 a cu. yd.? Ans.—$35.22.

What will be the cost of the materials in a cement basement floor 15 ft. wide, and 24 ft. long, the base consisting of 1-$2\frac{1}{2}$-5 mixture 4 in. thick and the top coat a 1-2 mixture 2 in. thick, when material costs the same as in the foregoing problem? Ans.—Base, $14.05; top, $11.19; total, $25.24.

THE CHILDREN'S OWN BOOK

BEFORE THE CHILD GOES TO SCHOOL

How to Learn the A B C
Forming Words
Reading
Counting and Figures

LITTLE LESSONS IN THINGS BEAUTIFUL

Making Pictures of Things We See
Music
Modeling in Clay
Basketry

LITTLE PROBLEMS FOR THE WISE

Problems
Riddles
Things Difficult to Say

MYSTERY AND MAGIC

Simple Experiments with Air and Water
Knots Used by Sailors and Builders
A Trick to Play with a Book
The Disappearing Dime
Making a Ball Vanish and Reappear
Conjuring

GAMES AND AMUSEMENTS

A Little Shadow Theater
The "Alice in Wonderland" Tub
Games to Play by the Fire
Nursery Games
Garden Games
Games to Play When Out Walking
Amusing Games for Halloween

THINGS FOR BOYS TO DO

An Easy Way to Make a Telephone
The Silent Messages of the Red Man
A Magic Lantern for Picture Post Cards
Simple Kites and How to Make Them
Measuring Distances by Sound
A Simple Flying Machine
The Pleasure of a Little Garden
How to Make a Paper Box

BOY'S CARPENTER SHOP

The Tool Box
Making a Set of Book Shelves
Joints
Staining and Polishing Wood

THINGS FOR GIRLS TO DO

How to Make a Girl's Workbox
How to Use the Needle
Collecting Ferns for a Rock Garden
The Little Petticoats
The Doll's Little Frock
A Little Winter Garden
How to Make Our Own Zoo
Things We Can Make at the Dinner Table

STORIES AND PLAYS

Stories With a Mora
Stories About Animals
Stories Connected with History
Nature Stories
Stories of the Imagination
Stories of the Sea
Stories of Patriotism
Stories of Childhood
Nursery Stories
Stories of Myths
Plays for Home Production
Fables and Folk Stories

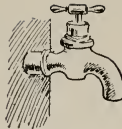
THUMBELINE FLOATED DOWN THE STREAM

Thumbeline became happy again, for everything she passed was so lovely in the sunshine, and the birds on the branches sang to her as she floated by with her pretty butterfly tied to the leaf of the water lily with her sash. (See page 371.)

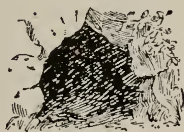
A P spells AP, which is not a word at all; but if we put a C, or an M, or a T in front of it in turn, we get real words.


CAP

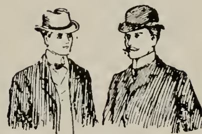

MAP


TAP

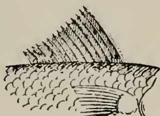
E N spells EN, and if we put first a D, or an H, or an M in front, we get DEN, HEN and MEN.

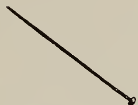

DEN

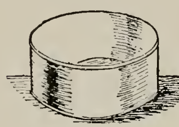

HEN


MEN

I N spells IN; put an F, or a P, or a T in front, and what do you find? Why, FIN, PIN and TIN.


FIN


PIN


TIN

One more. U G spells UG, and with an M, or a P, or an R in front, we have these very different words — MUG, PUG and RUG.


MUG


PUG

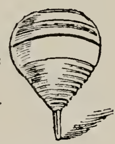

RUG

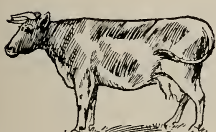
Or perhaps you can learn words better in this way:

When boys and girls are
fast asleep,
And beasts go out to
prowl,
If you're awake, you'll
often hear
The hooting of an
OWL.

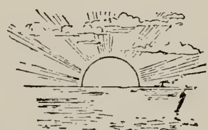

OWL

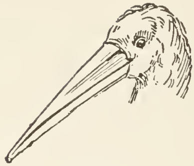
If father would give
me a penny,
I would soon be inside
of this shop.
It's the jolliest window
of any.
And oh, how I *should*
like that TOP!


TOP

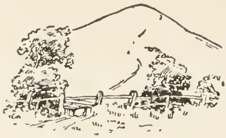

COW


BOY—TOY


SUN



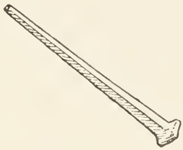
BILL



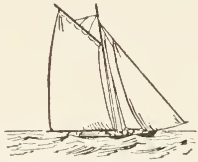
HILL

MILL

Then again, A I L spells AIL, and out of this you can make many words of four letters each. such as FAIL. HAIL, PAIL, and those given with pictures below.



NAIL

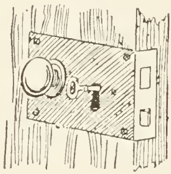


SAIL

TAIL

You will be able to make many other words from four letters. Perhaps you can make the next words out by yourselves

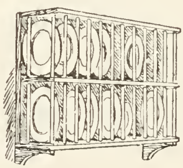
COCK



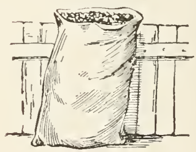
LOCK

ROCK

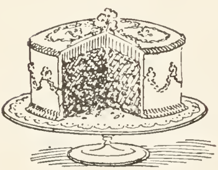
BACK



RACK

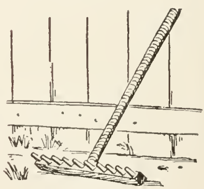


SACK



CAKE

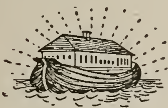
LAKE



RAKE

STORY QUESTIONS AND PICTURE ANSWERS

Before we go on to longer words, we should be sure that we can read all kinds of short, easy words. So in this lesson we will have a few more words of three or four letters each, and then we shall be able to go on to something better.


ARK

What did Noah build to save himself, and his family, and the animals from the flood ?

What bird did he send out after the raven ?


DOVE


LEAF

What did the dove bring back in its mouth ?

What did Jacob make for his little son Joseph ?


COAT


PIT

Into what did Joseph's brothers throw him ?

What did Joseph's brothers go down into Egypt to buy ?


CORN


CUP

What did Joseph's youngest brother, Benjamin, find in his sack ?

On what musical instrument did David play to comfort Saul ?


HARP


LION


BEAR

What wild beasts did David kill while he was watching his father's flocks ?

When David grew up, what did he become ?

KING

ONCE upon a time the Prophet Mahomet hid from his enemies in a


CAVE

Suddenly a


TREE

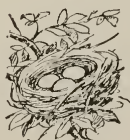
in full


LEAF

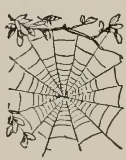
grew at the entrance of the CAVE. A


BIRD

built its


NEST

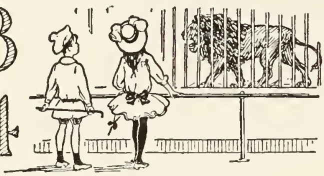
in the TREE, and a spider spun its


WEB

1 2

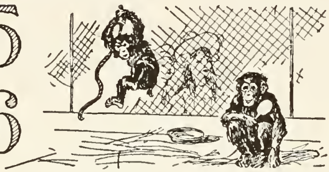
WE ARE GOING TO THE ZOO

3 4



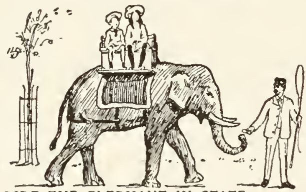
WE WILL HEAR THE LION ROAR

5 6



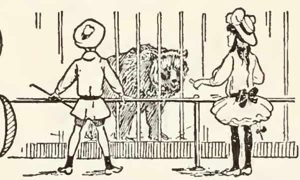
SEE THE MONKEY AT HIS TRICKS

7 8



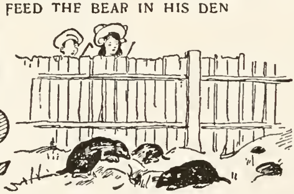
RIDE THE ELEPHANT IN STATE

9 10



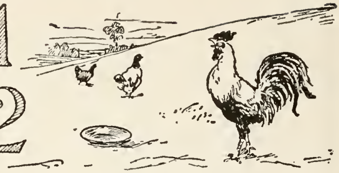
FEED THE BEAR IN HIS DEN

11 12



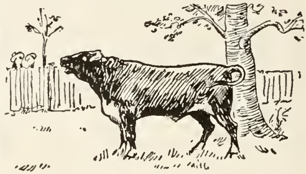
WATCH THE LITTLE MOLES THAT DELVE

1 2



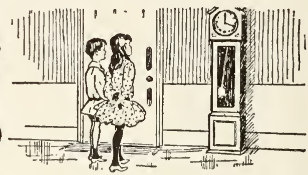
THE COCK CREW

3 4



HEAR THE BULL ROAR

5 6



THE CLOCK TICKS

7 8

CLEAN THE GRATE

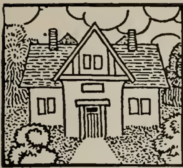
9 10

ARE PIT-MEN

11 12

FOR COAL THEY DELVE

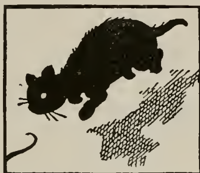
THE HOUSE THAT JACK BUILT



THIS is the house
that Jack built

THIS is the malt
that lay in the house
that Jack built.

THIS is the rat that ate the malt
That lay in the house that Jack built.



THIS is the cat
That killed the rat that ate the malt
That lay in the house that Jack built.

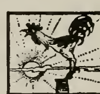
THIS is the dog that worried the cat
That killed the rat that ate the malt
That lay in the house that Jack built.

THIS is the cow with the crumpled horn
That tossed the dog that worried the cat
That killed the rat that ate the malt
That lay in the house that Jack built.

THIS is the maiden all forlorn
That milked the cow with the crumpled horn
That tossed the dog that worried the cat
That killed the rat that ate the malt
That lay in the house that Jack built.

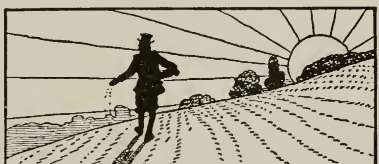
THIS is the man all tattered and torn
That kissed the maiden all forlorn
That milked the cow with the crumpled horn
That tossed the dog that worried the cat
That killed the rat that ate the malt
That lay in the house that Jack built.

THIS is the priest all shaven and shorn
That married the man all tattered and torn
That kissed the maiden all forlorn
That milked the cow with the crumpled horn
That tossed the dog that worried the cat
That killed the rat that ate the malt
That lay in the house that Jack built.



THIS is the cock that crowed in the morn
That wakened the priest all shaven and shorn
That married the man all tattered and torn
That kissed the maiden all forlorn
That milked the cow with the crumpled horn
That tossed the dog that worried the cat
That killed the rat that ate the malt
That lay in the house that Jack built.

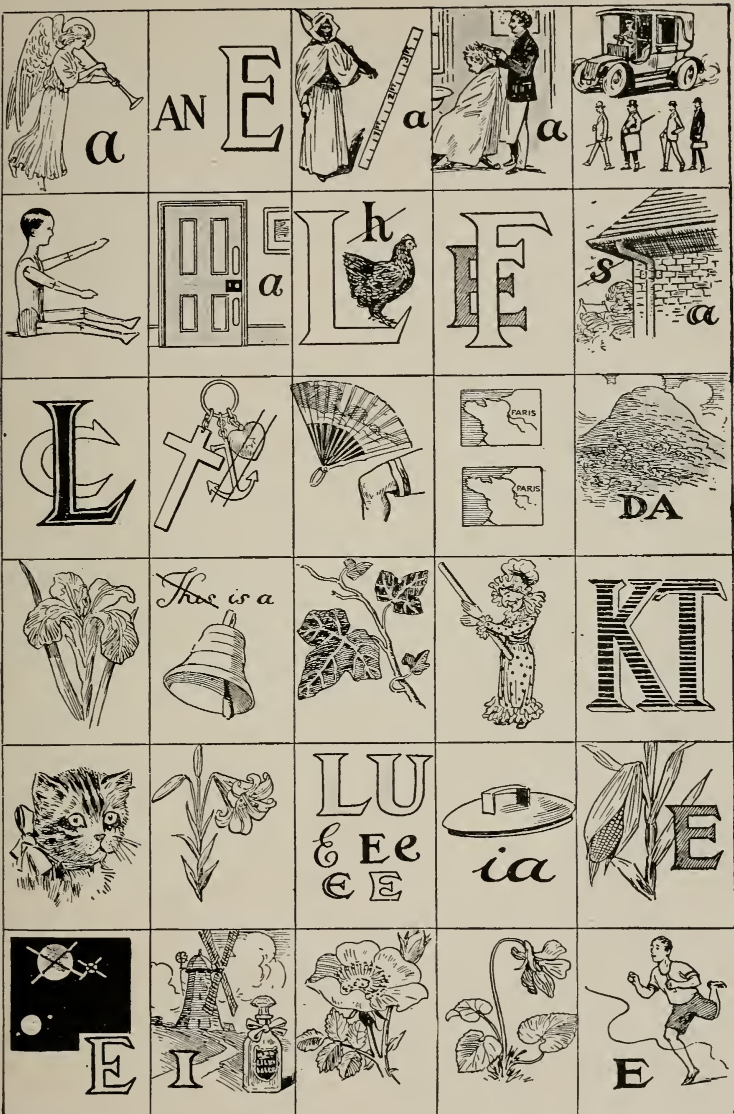
THIS is the farmer sowing the corn
That kept the cock that crowed in the morn
That wakened the priest all shaven and shorn
That married the man all tattered and torn
That kissed the maiden all forlorn



That milked the cow with the crumpled horn
That tossed the dog that worried the cat
That killed the rat that ate the malt
That lay in the house that Jack built.

MOTHER GOOSE IN REBUS

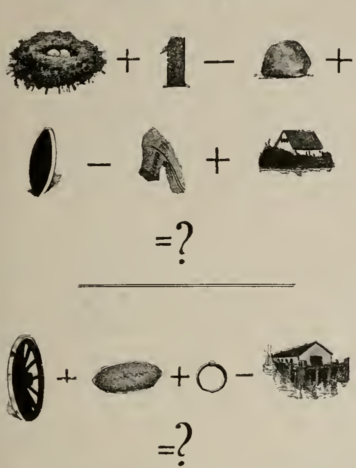
IS YOUR NAME IN THESE GIRLS' PICTURES



IS YOUR NAME IN THESE BOYS' PICTURES?

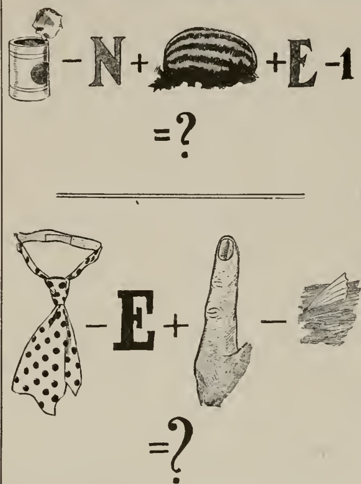
SAM LOYD'S PUZZLES

GEOGRAPHICAL PUZZLES 43



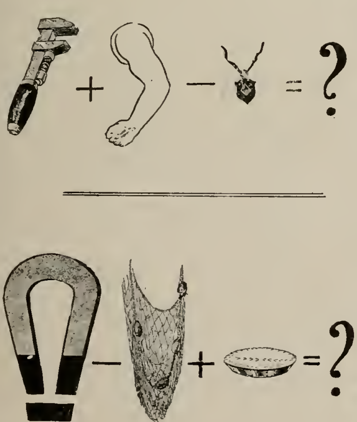
WHAT TWO AMERICAN CITIES DO THESE SUMS SPELL?

ZOOLOGICAL PUZZLES 69



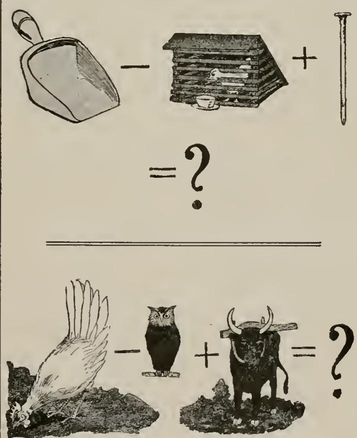
WHAT TWO ANIMALS DO THESE SUMS SPELL?

BIRD PUZZLES 87



WHAT BIRDS DO THESE SUMS SPELL?

PUZZLE SUMS 76



NO. I. WHAT REPTILE DOES THIS SUM SPELL?
NO. II. WHAT ANIMAL DOES THIS SUM SPELL?

SAM LOYD'S PUZZLES

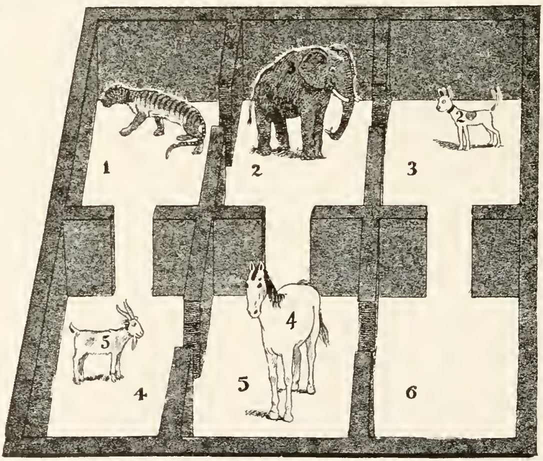
PUZZLING NOISES

99

The young musician is surrounded by a variety of noises. Number one is plainly a squeak. How many other noises can you find in the little pictures?

THE PEN PUZZLE

117



In how few moves can you place each of the animals in its proper pen, without ever having two in the same pen? The numbers on the animals should correspond to the numbers of the pens.

43 1st. Nest + One – Stone + Wheel – Heel + Ark = Newark.
2d. Wheel + Pie + Ring – Pier = Wheeling.

69. 1st. Can – N + Melon + E – One = Camel.
2d. Tie – E + Finger – Fin = Tiger.

87. 1st. Wrench + Arm – Charm = Wren.
2d. Magnet – Net + Pie = Magpie.

76. 1st. Scoop – Coop + Nail = Snail.
2d. Fowl – Owl + Ox = Fox.

99. 1, Squeak; 2, Squall; 3, Howl; 4, Roar; 5, Bellow; 6, Ring; 7, Growl; 8, Wail; 9, Bark.

117. The animals are rearranged into their proper pens by moving them in the following order: 4, 3, 2, 4, 3, 5, 1, 2, 4, 3, 5, 4, 2, 1, 4, and 5.

BY PERMISSION OF DAVID McKAY CO.

HOW TO DRAW HUNDREDS OF FACES

With the diagram on this page we can draw hundreds of different pictures, even though we may not be artists in any sense of the word. First of all, we should take a piece of good tracing-paper and trace the diagram upon it quite carefully and accurately. Then we should ink over the lines, and when the ink is quite dry paste the tracing-paper with the design upon a piece of cardboard. To do this, cover the card with a smooth paste and lay the tracing-paper the tracing-paper round until one of the pairs of eyes comes into position within the outline of a face that we have drawn. Trace the eyes with pencil, and finally turn the paper round to another position and trace a nose and mouth. We now have a complete face with eyes, nose and mouth, hair, and hat.

By ringing the changes and drawing the different eyes in the different face outlines, and putting sometimes one hat or mouth and sometimes another, we are able to make

BY FOLLOWING THE DIRECTIONS, WE CAN, FROM THIS DIAGRAM, DRAW HUNDREDS OF FACES

upon it, smoothing out all wrinkles with a clean cloth. When this is dry, we are ready to draw any number of faces. Take a piece of tracing-paper and pin it down upon the card, pressing the pin through the centre of the diagram where a star is marked. Now we must trace any one of the hats upon the transparent paper. Then let us turn the paper round until the hat that we have drawn comes over one of the other hats in the diagram. Now trace the shape of the face that appears under our hat. Again turn hundreds of different pictures. There are one or two things to remember if we want to be successful in thus producing an imaginary portrait gallery. The tracing-paper must be pinned down firmly upon the card and must not be allowed to shift about, or the different parts of the different faces will not join up properly. Then we should use a soft black lead pencil in tracing the faces, and we must not press too heavily or we shall indent the card and spoil the diagram. We can ink over the pencil-lines afterwards.

DIFFERENT EXERCISES WITH DUMB-BELLS

Rembrandt in his studio

LESSONS IN THINGS BEAUTIFUL AND USEFUL

SHAKESPEARE says in one of his plays that if we could cast off this "muddy vesture of decay" we should be able to hear the "music of the spheres." He means that if we were more thoughtful and quiet, we should find that all the sights and sounds about us are really beautiful and pleasant and that if they do not seem so to us the fault is not in these things, but lies in ourselves.

Now artists—who include poets, writers of books, musicians, painters, designers, sculptors, and architects—are those who hear this "music of the spheres," and put it down so that the rest of us may hear it too.

Let us try to find out how this music is heard by painters and designers, architects and sculptors, and how they write it down. We know all beautiful things by our minds or our souls. Our eyes, ears, touch, taste, and smell are only the roadways to our true selves, so that music may travel by any one of these paths, and not by the ear roadway only.

And music does not mean only pleasant sounds coming together; it means also beautiful shapes falling side by side, or colors, placed one against another. So that, when we see a beautiful picture, or a piece of sculpture, or a grand building, or a lovely decoration, the music of the arrangement of the shapes is appealing to our eyes, and giving us joy and pleasure quite apart from the subject of the work. In these pages are some pictures with their musical shapes. Look carefully at them, and see if you can find any of this music. Look carefully to see if one line appears to be the continuation of another, though there is no actual connection. Join these lines, and note the beautiful shape they enclose.

Again, boys and girls, men and women, the flowers and trees, the birds and animals, the earth itself are all struggling for existence. The very winds, the clouds, and the sunshine are all the results of struggling, of fighting, of victory, and of failure.

Joy and sorrow touch everything on earth, and he is an artist who is able to picture this joy and sorrow for us so that we can feel them strongly.

So an artist must possess two things—an eye quick to see and love beautiful shapes, and a mind quick to feel and to respond to the joys and and feelings, and not be ashamed or afraid of them.

Now, though drawing is music, it is also speech, and we draw in order to tell to others facts that we could not put so well into any other form, things that give us pleasure which we would share with others.

How the hand of the artist draws a picture

struggles that all the things about us are enduring—that is, he must want to rejoice with glad things, to be sorrowful with sad things, to admire all brave efforts, wherever they are made and whatever makes them.

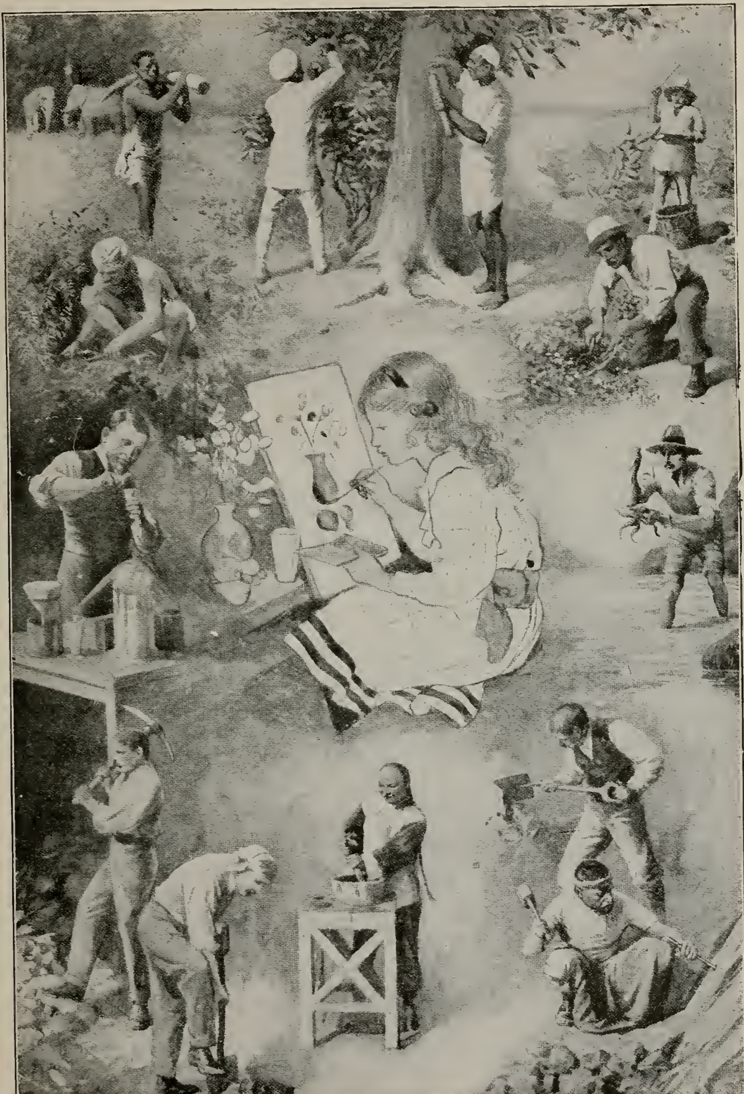
All of us possess more or less these two essentials—the quick eye and the sympathetic mind. We do not always realize it, and we are too often afraid of our feelings. Now this is wrong, for if we would become brave and tender men and women, capable of doing big and effective work in the world, we must reverence our thoughts

The completed picture

It is not possible for us all to become great artists, but we should all be able to read what the artist is eager to tell us in his work, and by reading his pictures our lives will become bigger and more sympathetic. We shall begin to see the beautiful laws of order and music that are at the heart of everything, and then we shall want to link this music together ourselves, in order to make others feel it as we do, and we, too, may be artists, creators. So let us set about our lessons in this wonderful subject, whereby we shall become friends with the things around us.

Materials: For the little ones we will choose white and colored crayons, these should be soft and not greasy. The mind must work readily through the fingers and the muscles of the hand must become very sensitive, which cannot happen if hard unyielding pencils are used. You who are older may use pencils, which must be soft known as B or BB so that they will yield readily to the slightest pressure. If you have a paint box you must learn to use it. These boxes containing moist colors in pans or tubes are preferable. With these you will need

THE WORLD AT WORK TO FILL A PAINT-BOX



All over the world men work hard in order to fill this little girl's paint box. Here, reading from left to right, we see men collecting ivory for black, insect-cells for crimson lake, resin for gamboge, cochineal for carmine, the indigo plant for indigo, the madder for brown, iron and potassium for Prussian blue, cuttlefish for sepia, earth for sienna, mercury for vermilion, and mineral for ultramarine.

a pointed camel's hair brush, number six, a jar for water, and a small sponge-box, water and sponge must be kept quite clean. Untidy materials make an untidy mind.

Use white or colored paper to work on. There is a cheap unglazed, soft-textured, warm gray paper which is delightful, and which may be obtained from any dealer in artists' materials. Ordinary unglazed brown paper is good if neither too light nor too dark. Do not let your paper become creased or crumpled, keep it flat and neatly together in a portfolio. The portfolio may be bought or made at home from two pieces of cardboard joined together at the back and fastened at the front with a piece of tape.

A small drawing board will be necessary to which the paper should be fixed by four thumb tacks or drawing pins. When drawing do not lay your board flat upon the table, let it slope toward you resting the top against the table.

Sit well away from your work, hold crayon, pencil or brush lightly with end of same pointing into the palm of your hand, and your hand scarcely touching the paper as you work.

Face squarely the object you wish to draw so that you may glance quickly from your drawing to the object. Hold your work frequently at full arms length from you, or better still stand away and look at it as though you were a teacher correcting exercises.

Forget yourself and do not be afraid of your materials. Think only of putting down on the paper just the appearance of the object before you.

Things to Draw

All living things, if they have been allowed to grow up without suffering from accident, have beautiful shapes. We cannot do better than to draw, from every possible view, the things we see about us and so learn to recognize a beautiful shape before we consider the second great essential underlying all art—that is, the true self of everything.

When using crayons do not press heavily or you will fill every crevice of your paper, then the color of the paper will not show through the crayon as a soft gray. If your drawing is not

This is how the laurel spray should look when it is drawn from memory in black chalk on brown paper.

If we have chosen ivy leaves to draw instead of laurel leaves, this picture will do to compare our drawing with.

good, do not try to rub it out, make it again and again.

Drawing and Painting a Spray of Leaves

Let us find and draw or paint a spray of leaves. Any kind of leaves will do but since all leaves and flowers change quickly after they are picked we will need to work rapidly. You will notice that wherever the leaf springs from the stem there is a little swelling; sometimes it is much bigger than at other times

The stalk of the leaf is not the same thickness all the way down. Some kinds of laurel leaves are rounded at the tips and where they join the stalks and some are pointed. Whichever kind of leaf we have chosen, we must look at all these things and notice the different shapes, begin with the big stem. Notice if it curves or bends, then draw the leaf-stalks and then the leaves themselves. We shall find it better not to draw the leaves with a single line round them at first, but to rub the chalk sideways on the paper, getting the direction the leaf takes carefully, and drawing it big. The pictures show laurel and ivy, but any leaves must be drawn in the same way, beginning first with the long stems. We can practice drawing the spray with a brushful of color in green paint to match the shade of the leaves, or in brown or black paint like the picture above. Moisten the paper with the damp sponge first. If the paper glistens when you hold it level with the eye, it is too wet.

A good, bright green is made by mixing Prussian blue, gamboge, and burnt sienna. A good dark green is made by mixing together indigo and burnt sienna or Prussian blue and Vandyke brown. We shall find that there are a great many ways of mixing greens when we know our paints.

Now we have to make a copy of our laurel leaves, painting them straight away on white paper.

Here is a picture of a spray of ivy leaves painted on white paper. Remember to start with the stalk.

Remember that we draw with our mind, and that our hands can do only what our mind, or soul, tells them. If we do not look at the object carefully, and judge its edges carefully, our hands cannot put the truth down.

A PLAY LESSON

Now let us have a play lesson. Take one of the things you think you can draw, place it before you, and look at it for a minute or two. Then cover it up and try to draw what you have seen from memory.

When you have finished your drawing, uncover the object, get up from your seat, stand behind your work and compare it with the original. Be a teacher, and do not allow any fault to go uncorrected.

Do this with every object—the cat, the dog, your toys, leaves, fruits, and flowers—about you. Look at it, turn away and draw it; then change yourself into a teacher and criticize. You must be a judge, and bring up every accusation you can. You must definately and fairly judge each one—length against breadth, curve against curve. You cannot realize too clearly how important this part of your work is.

You will never draw freely, or forget your pencil and paper and yourself, until you can draw from memory. It is only then that you can be said to know what an object is like.

THE LITTLE CLAY MODELER AT HOME

A SIMPLE LESSON IN AN INTERESTING PASTIME

THOSE of us who have ever done modeling will agree that it is a delightful pastime. There is no end to the things that can be made out of those little lumps of clay which look so uninteresting till they have been pinched and poked and rolled into all manner of fascinating shapes. And modeling is as useful as it is delightful, for it not only makes practical use of our patience and our perseverance, but it trains the senses of sight and touch, and makes us observant, and consequently more accurate and self-reliant.

The "tools" that are needed are few in number, and quite inexpensive. All that is required is a piece of clay, or, better still, of plasticine—which is cleaner to work with and better in many ways—an unframed slate, and one's fingers. Of course, the more plasticine the better, and the gray color is the most suitable for the work it is proposed to do. It can be bought at almost any shop in which artists' materials are sold, and a slate may be procured from a shop dealing with school requisites.

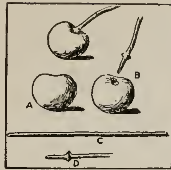
Just a word as to the care of the materials. Keep the plasticine in a moderately cool place, and when not in use see that it is kept free from dust or grit. After long usage, plasticine has a tendency to become stiff and difficult to manipulate. This is owing to the evaporation of the oil which it contains. When it becomes so, work a small quantity of vaseline into it by kneading in your hands until it becomes plastic again. The slate should always be scraped clean before each model or exercise is attempted.

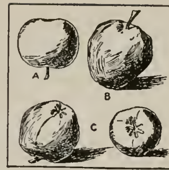
The first few models will not need to be worked on the slate at all; they must be done almost entirely in the hands and with the finger-tips.

Let us take the first picture—a model of a bunch of cherries. Break off—do not cut—a lump of plasticine and roll three balls about the size of cherries. Slightly press the top of each to give the shape shown at A, and in the center of each depression bore a hole, as at B, with a match, to receive the ends of the stalks. For the stalks, roll out on a clean slate a long thin strip, as at C. To do this successfully, and to preserve equal thickness throughout the length, requires care. The small piece of plasticine used should be rolled beneath the flat hand on the slate, and not between the two hands. Press evenly as the strip begins to lengthen, and move the hand slowly to the right as you proceed with the rolling. The right thickness to obtain is equal to that of an ordinary match. This is, of course, a little thicker than the natural stalks of the cherries would be; but we take a little liberty, for if we reduced them to such a degree they would hang limply down. Divide the strip into three equal lengths, and make the little thickening, as shown at D, by lightly holding the strip between fingers and thumbs and pressing with both hands at once towards the thickening. Fix the stalks into the cherries, pinch the three ends together, and the model is complete.

Our other model is an apple, and this will demand a greater effort. Of course, there are many shapes of apples and a round one as at A, with just the end depressions and the stem, would be very easy to make.

But the apple we wish to do is one





with a well-defined and somewhat angular shape, of the type shown, exaggerated a little, in the illustration marked B. This is much more difficult. The size of the model must be left to the worker for it must not be too big to handle comfortably. First, make a ball as before, and, with the real apple before you, work it into the same shape adding to or taking from the model as you proceed. You will find the finger-tips very useful for this. Notice all the little angularities of surface, look well at the copy from every side, and compare the two constantly as you work. Do not be satisfied merely with the model of an apple, but try to make a faithful copy of the apple before you. The stem is inserted in a similar manner to those of the cherries, and the markings at the opposite end are made with the match end as at C.

The model should have a smooth finish, and this can be done by lightly smoothing with the forefinger. It must be held carefully and without undue pressure while this process is being carried out.

BASKETRY

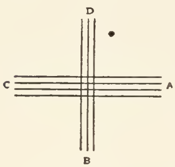
Basketry—a Doll's Christmas Hamper

WHILE we are enjoying the good things that Christmas brings, we surely must not forget our dolls. Here we are going to learn how to make a little doll's hamper, and later on to fill it with Christmas "goodies" which we shall find it quite easy to model with our fingers out of clay.

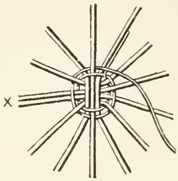
First, then, we will make the hamper, for which we must carefully measure off seven pieces of "No. 4" (or fairly thick) cane. Most of the big toy-shops sell cane for cane-weaving, or, of course, it can be bought from any basket factory.

If we make the hamper three inches high, each piece of cane must be sixteen inches long. These seven lengths of cane are for the foundation of our hamper, and we will call them the "spokes" whenever we refer to them, as they remind us of the spokes of a wheel.

Form a cross with four spokes across and three spokes upright, the three upright spokes being in front as in picture 1.



1. Position of the canes



2. Beginning to make the basket

Hold these between the thumb and first finger of the left hand.

Our next step is to select a long piece of "No. 1" (or fine) cane, which we shall call the "weaving-cane," as it weaves in and out the spokes, just as the threads of any woven material pass over and under each other.

We must hold the weaving-cane in our right hand, a few inches from one end. Place this *end* of the weaving-cane at the dot in picture 1, and pass it under the four spokes at A, over the three spokes at B, under at C, and again over at D. We draw this as tightly as possible and pass the cane under the tiny end to form a *tie.*

In picture 2 we are able to see just how the weaving-cane travels, if we follow it up from the letter L.

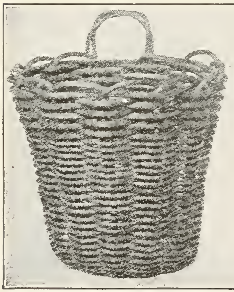
From this point we weave over one spoke and under the next until we have passed eight spokes, which brings us to the left side of the picture where we see two spokes taken together. Some of us may think this a mistake, but in weaving we must have an odd number of spokes, because where the weaving-cane passes over one time, the next time it must go under.

At the place marked X in picture 2, we take two spokes together and treat them just as one spoke.

By taking the two together it fastens the odd number in quite securely. Continue the weaving over and under, taking care, when you come to the spoke with the little bit beside it, that you treat that spoke and the little bit as one. We must remember always to weave in the direction in which we began.

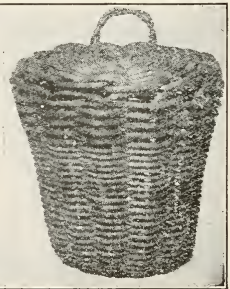
If we have done our weaving correctly, the weaving-cane will now pass under the spoke over which it went the last time round.

We must continue our weaving until we have covered about one inch from



3. The basket without the lid

4. The lid of the basket



5. The basket complete

the center of the basket. Then cut off one of the two spokes taken together and what is left of the tiny bit of weaving-cane where we started.

One very important thing is the right way to hold our work. Hold the work in the left hand perpendicularly, the weaving-cane being held in the right hand just like a skipping-rope about two inches away from the basket. We now slip the first finger out and hold the cane between the thumb and the second finger.

Don't think Mr. First Finger has nothing to do. He is a very important person, and acts as a guide to Mr. Weaving-cane, guiding and pressing him always into his proper place. We must also be very careful never to pull the weaving-cane, but to bend it round the spokes, moving the basket up and down at the same time.

Every touch of our fingers has a permanent effect on the ultimate shape of our basket, and no subsequent pressure will alter it. We shall be able to begin a second basket much better after we have thus learned to weave properly.

How are we to turn up the cane for the sides of the hamper?

We notice the alternate spokes are on the top of the weaving-cane. These spokes we bend away from us. Weave round once again, when, of course, the other spokes are on the top. These also must be bent away from us. We continue weaving as before, taking care to keep the spokes nearly at right angles to the bottom of the basket.

We must remember, as we weave the side of the hamper, when the weaving-cane is going behind a spoke, to draw that spoke back with the guiding finger and slip the whole hand behind it to put the weaving-cane in place. The more we press on the spokes when drawing them back, the more the sides of our basket will slant outwards.

By this time the side of our hamper measures two and a half inches from where we turned it up. Here we take a length of No. 4, or rather thick cane to weave the other half-inch. An important point to learn just now is how to join a new piece of cane so that it will be least observable.

We must always finish off the end of the old weaving-cane, when we have come under a spoke, by pushing the loose end of the weaving-cane down the side nearest to us of the same spoke.

Take a new piece of weaving-cane and pass the end down the far side of this spoke. Both the old and the new weaving-cane pass behind the same spoke, but the join does not show on the right side of the basket.

To finish our basket we cut an inch off each spoke with the exception of two, which we leave to form the handle, as seen in picture 3. Each spoke must be turned back the opposite way from which we have been weaving, and pressed down the far side of the next spoke until it lies level with the last line of weaving. To form the little handle, we cross the two spokes and push the ends down so that one end goes in where the other starts from.

Having made our hamper, we must turn our attention to the lid for it, which is made exactly as the bottom of the hamper, using seven spokes about six inches long.

When the weaving exactly fits the top of our hamper, we finish by pushing the spoke-ends down the sides of their left-door neighbors.

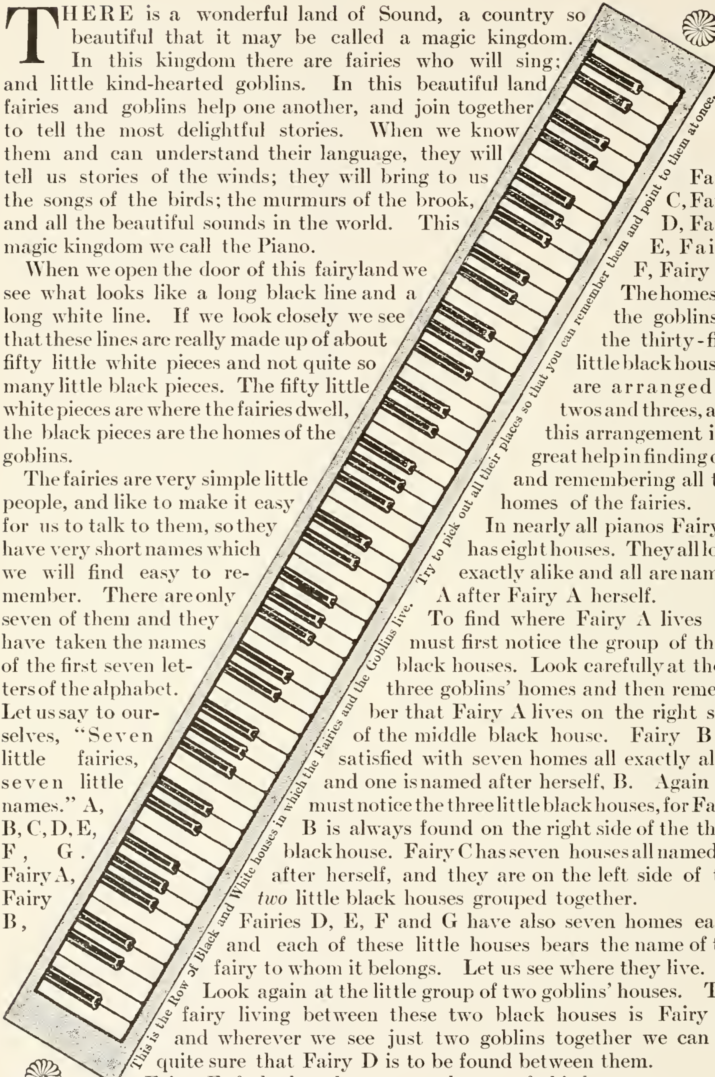
Basket-weaving is most fascinating work when once we have acquired the art of weaving easily; therefore it is worth while to practice weaving, as from this small beginning it is possible to make any number of very pretty and useful articles.

THE WONDERFUL LAND OF SOUND

THERE is a wonderful land of Sound, a country so beautiful that it may be called a magic kingdom. In this kingdom there are fairies who will sing; and little kind-hearted goblins. In this beautiful land fairies and goblins help one another, and join together to tell the most delightful stories. When we know them and can understand their language, they will tell us stories of the winds; they will bring to us the songs of the birds; the murmurs of the brook, and all the beautiful sounds in the world. This magic kingdom we call the Piano.

When we open the door of this fairyland we see what looks like a long black line and a long white line. If we look closely we see that these lines are really made up of about fifty little white pieces and not quite so many little black pieces. The fifty little white pieces are where the fairies dwell, the black pieces are the homes of the goblins.

The fairies are very simple little people, and like to make it easy for us to talk to them, so they have very short names which we will find easy to remember. There are only seven of them and they have taken the names of the first seven letters of the alphabet. Let us say to ourselves, "Seven little fairies, seven little names." A, B, C, D, E, F, G. Fairy A, Fairy B, Fairy C, Fairy D, Fairy E, Fairy F, Fairy G. The homes of the goblins—the thirty-five little black houses, are arranged in twos and threes, and this arrangement is a great help in finding out and remembering all the homes of the fairies.



Try to pick out all their places so that you can remember them and point to them at once.

This is the Row of Black and White houses in which the Fairies and the Goblins live.

In nearly all pianos Fairy A has eight houses. They all look exactly alike and all are named A after Fairy A herself.

To find where Fairy A lives we must first notice the group of three black houses. Look carefully at these three goblins' homes and then remember that Fairy A lives on the right side of the middle black house. Fairy B is satisfied with seven homes all exactly alike and one is named after herself, B. Again we must notice the three little black houses, for Fairy B is always found on the right side of the third black house. Fairy C has seven houses all named C, after herself, and they are on the left side of the *two* little black houses grouped together.

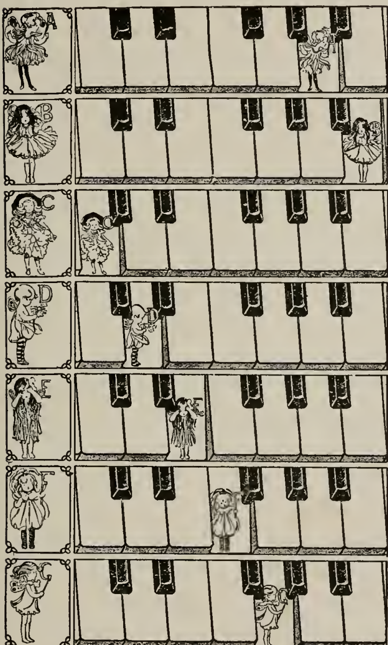
Fairies D, E, F and G have also seven homes each, and each of these little houses bears the name of the fairy to whom it belongs. Let us see where they live.

Look again at the little group of two goblins' houses. The fairy living between these two black houses is Fairy D, and wherever we see just two goblins together we can be quite sure that Fairy D is to be found between them.

Fairy E feels that she wants to be one of this happy party and she has her home next to D, so that Fairy E is on the right side of the second black house.

Fairy F and Fairy G are like a group of three goblins, so Fairy F lives on the left of the first of the three black houses while Fairy G lives next door to her on the left side of the middle black house.

Now that we have found out where all the little fairies live, let us go to



Home of the seven fairies

the piano and see if we can find the little houses. Every day we should enjoy a real game of play with the fairies and goblins in the magic kingdom. We can think we are the postmen of fairyland and each morning we must take the fairies their letters, being sure to go to the right houses and careful not to forget any of our little friends.

Let us ask the fairies to play a game with us and see if we cannot learn to sing the note of each. We will knock first at Fairy C's door. We will choose that house of hers which is almost in the middle of the long white line, remembering that her houses are always found on the left-hand side of the group of two goblins' houses.

To knock at her door so that we may really hear her voice in answer, we must press down the little white piece very gently and firmly.

Listen! Do you hear her? It is Fairy C's voice. Try to sing the same sound exactly. Try a great many times, and then, when we think we know it quite well, we will run away to the end of the room and sing it again, coming back very quickly to the magic kingdom to see if we have remembered it rightly.

Fairy C likes to hear us say "This is Fairy C's voice," and she will always sing if we go to her house, C, and press the door very gently.

When we have played as long as we like with Fairy C, we may go to her next-door neighbor, Fairy D. Fairy D's voice is not quite like Fairy C's. We will press the door here, too, and listen to the answer, and then try and sing the same sound.

But we must not forget Fairy C's voice, so we will touch the door again and listen. Now we will go back to Fairy D, to be quite sure that we know each fairy's voice.

But there are more fairies, and so we go to Fairy E's house and learn her little "note," and then to Fairy F and Fairy G, until we reach Fairy C's second little house.

If we have a fairy concert every day we shall soon come to know all the beautiful fairy voices quite well.

LITTLE PROBLEMS FOR THE WISE

WHEN WAS THE WATCH RIGHT?

1. At noon on Monday Herbert asked his father what o'clock it was. His father told him that it was noon, and said that his watch was two minutes fast. On Wednesday morning Herbert again asked the time, and his father replied that the exact time was eight o'clock, but added that his watch was one minute slow. Herbert then told his father at what time his watch had been exactly right. Could you have done it?

ANSWER.—From noon on Monday to 8 o'clock on Wednesday morning is 44 hours. His father's watch, therefore, lost 3 minutes in 44 hours. But it was right when it had lost only 2 minutes, which it would do in two-thirds of 44 hours—that is, in 29 hours 20 minutes. This number of hours from noon on Monday would make it 5:20 on Tuesday afternoon.

HOW MANY DUCKS?

2. "How many ducks did you drive home?" asked Farmer Bell.

"There were two ducks in front of a duck, two ducks behind a duck, and a duck between two ducks," was the reply.

What was the number of ducks?

ANSWER.—Three.

WHAT VEHICLES WERE SENT?

3. An order had been received at a garage for automobiles for a party of fifty-nine. The manager had automobiles to seat nine and cabs to hold four, and he sent some of each, so that everyone had a seat and there was no seat vacant.

How did he do it?

ANSWER.—Try one automobile first. This will seat 9 and leave 50. There is not an exact number of 4's in 50, so that they could not be seated in cabs. Next try 2 automobiles. These will seat 18 and leave 41, which again cannot be seated in cabs. Next, 3 automobiles will seat 27 and leave 32. Now 8 cabs will seat exactly 32, so that the manager must have sent 3 automobiles and 8 cabs.

HOW DID THE SHEEP STAND?

4. "I saw an odd sight the other day," said Jones. "Two sheep were standing in a field, one looking due north and the other due south. How do you think that each could see the other without turning round?"

Can you give the answer?

ANSWER.—This is what is usually known as a "catch," and the answer is that, as they stood, they faced each other, one looking north and the other south.

THE CLOCK STRIKES TWELVE

5. John and his sister stood under the church tower and heard the clock strike six. John looked at his watch while it did so, and said to his sister: "It took 30 seconds to strike six." His sister replied: "Then how long would it take to strike 12?" John replied, "Sixty seconds, of course!" John was wrong. What is the correct answer?

ANSWER.—The clock would take sixty-six seconds to strike twelve. Between the first stroke and the sixth stroke there were five intervals of time, each interval being six seconds. Between the first and the twelfth stroke there were eleven intervals of time, each of six seconds, so that the clock would take sixty-six seconds to strike twelve.

HOW MANY EGGS?

6. If a hen and a half lays an egg and a half in a day and a half, how many eggs will one hen lay in six days?

ANSWER.—Four eggs. One hen would lay one egg in a day and a half—that is, two eggs in three days, or four eggs in six days.

Twelve eggs in basin

7. There are 12 boys, and on the table is a basin with 12 eggs. Each boy took one egg and there remained one egg in the basin. How was this?

Answer.—The last boy took the basin as well as the egg in it.

The farmer and the tramp

8. A tramp lies down for a nap at the side of a haystack, and hears the farmer approaching. He runs round and round the stack chased by the farmer. They start from opposite corners, the tramp taking forty seconds to run completely around and the farmer thirty seconds. How often must the farmer run around before catching the tramp?

Answer.—As the tramp runs round the stack in forty seconds, and the farmer in thirty seconds, the farmer can run round four times in the same time that the tramp takes to run round three times. This means that in four rounds run by the farmer he would gain one round upon the tramp; but, as the tramp had a start of only half a round, the farmer would overtake him after running only two rounds, which is the answer.

How many persons were they?

9. Brown arrived at the inn to arrange lunch for his party. "How many of you are there?" asked the innkeeper. "Well, we represent father, mother, uncle, aunt, sister, brother, nephew, niece, and two cousins."

What was the fewest number that could be in the party?

Answer.—There were four in the party. The father and mother were brother and sister, one having a son and the other a daughter. The children were cousins, therefore, nephew and niece, and the father and mother were thus uncle and aunt.

How many stamps had they?

10. Three children—Jack, Frank, and Harry—divided some postage-stamps among them. Jack had half of them and one more; Frank had one more than half of those left; Harry had the remaining three. How many stamps were there?

Answer.—First let us find how many stamps were left when Jack had taken his share. Since Frank had one more than half, Harry must have had one less than half. You know that Harry had three, therefore four must have been half of the quantity that Harry and Frank divided. Half of eight is four so Frank had five. Now we must find how many Jack had. Jack's share was one more than half the total quantity and therefore the quantity divided by Frank and Harry must have been one less than half the total. Frank and Harry's share came to eight as we have seen and the half of the total quantity being one more than eight was nine. Jack had ten which is one more than half the total quantity and thus there were eighteen altogether.

Whose portrait is it?

11. One of the problems that have most puzzled our fathers and mothers is the old problem of a man looking at a portrait, saying: "Brothers and sisters have I none, but this man's father is my father's son." Whose portrait is it?

Answer.—If a man says that he has no brothers and sisters, his father would have only one son—himself. Thus, if what he says is put in simple language it is: "That man's father is myself." This means that the picture at which he looked was that of his own son.

Did George walk round the monkey?

12. George was trying to tease the monkey which was seated on the top of a barrel-organ. But, although he

walked all round the barrel-organ, the monkey always turned so as to face the boy the whole time.

When the boy has walked round the organ, has he walked round the monkey?

ANSWER.—No. George never sees the monkey's back, which he clearly would do if he walked round the monkey.

HOW LONG WAS THE STRING?

13. A boy had two pieces of string, one of which was just twice as long as the other. He cut 6 inches off each piece, and then found that one was just three times as long as the other How long were they at first?

ANSWER.—To begin with, one piece of string was 12 inches long and the other piece 24 inches. After cutting 6 inches off of each the shorter piece was 6 inches long and the longer piece 18 inches long.

HOW FAST WAS THE HORSE WALKING?

14. I was walking along a country road steadily at the rate of four miles an hour. I saw a horse and cart going in the same direction, and when I saw them they were exactly 220 yards in front of me. I overtook them in 15 minutes. At what rate was the horse walking?

ANSWER.—In 15 minutes I had gone one mile and the horse 220 yards less than one mile. In one hour the horse would walk 880 yards less than four miles—that is three-and-one-half miles in one hour.

HOW MUCH DOES A BRICK WEIGH?

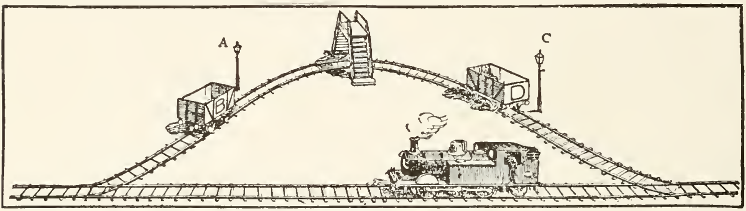
15. A brick weighs six pounds and half of its own weight. What is the weight of the brick?

ANSWER.—The brick weighed 12 pounds. The weight of each of the two halves is the same, so that if a brick weighs half of its own weight and 6 pounds, the 6 pounds must represent the other half.

HOW MUCH WATER WAS SPILLED?

16. A boat leaving a wreck had water to last 13 days, allowing each man one quart each day. After five days some water was spilled and one man died on the same day. The water then lasted just the expected time. How much water was spilled?

ANSWER.—The amount spilled would have served the man who died for 8 days, and this, at 1 quart each day, would have been 8 quarts.



How did the engineer change the cars?

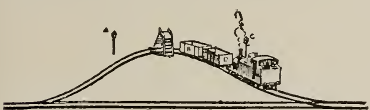
HOW DID THE ENGINEER DO IT?

17. The illustration represents a railway line with a short loop line extending from one part of the main line to another part of the main line. In the middle of the loop line is a bridge, under which a car can be pushed by the engine, but which is too low for the engine itself to pass through. On the left side of the loop line, near the lamp-post marked A, is a car marked B, and on the right side of the loop line, near the lamp-post marked C, is a car marked D. The engineer is told to take car B to the lamp-post C on the right side, and to

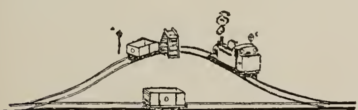
take car D to the lamp-post A on the left side, leaving them at these points, and then to bring his engine back to the main line. The main line extends further at each end than is seen in the picture.

How did he perform his task?

Answer.—The engine goes forward along the main line, backs up the left side of the branch line, and pushes car B through the bridge. Then the engine comes down the branch line, to the main line, along the main line to the right of the picture, then up the right side of the branch line, and pushes car D up to car B. At this stage the position is like this:



Then the engine pulls down both cars, brings them both to the middle portion of main line, where it leaves car B (which is the one farthest in front of it), and, going back again with car D, pushes it up the right side of the branch through the bridge. The position is then like this:

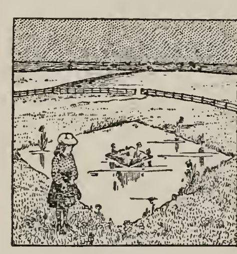


Now the locomotive comes back again to the main line, takes car B, and leaves it at the post C, finally coming down again along the main line, up the left side of the branch line, and pulls car D into its place. It can then return to the main line alone.

How does Julia get the eggs?

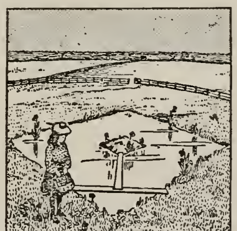
18. Dora and Julia gather the eggs on the farm. One morning Dora discovers that several eggs have been laid on a small square island in the middle of a square pond, and, having no plank long enough to reach across, she leaves the eggs alone.

Julia sees them the next morning, and, looking round for a means to reach the island, finds two planks, neither of which will quite reach from the edge of the pond to the island. But they are her only means of access to the eggs, and, placing them so that she can step across them, Julia reaches the island and takes the eggs home in her basket. How does Julia reach the island?



How does Julia get the eggs?

Answer.—Julia put the planks as shown in the picture, and thus reached the island.



How Julia got the eggs

Riddles

1. To what island should hungry people go?
2. Why is a policeman like an aeroplane?
3. Why are watches like grass-hoppers?
4. What tree is nearest to the sea?
5. Why is charity like an um-brella?

6. Why is the eye like a very severe schoolmaster?

7. What flower is most likely to be found in the shop of a shoemaker?

8. Why is Sunday the strongest day?

9. What flower would you wish for when oppressed with woe?

10. Why are pen, ink and paper like fixed stars?

11. Why are hay and straw like spectacles?

12. Ten men's strength and ten men's length, and ten men cannot set it on end, yet one can carry it.

13. What is that which goes through the wood yet never touches the ground or the trees?

14. What tradesmen are always robbing themselves?

Answer.—(1) The Sandwich Isles; (2) Because he takes people up; (3) Because they move by springs; (4) The beech; (5) Because it is most useful when most widely extended; (6) He always has a pupil under the lash; (7) Lady's slipper; (8) Because the others are all week (weak) days; (9) Heartsease; (10) Because they are stationery (stationary); (11) Because they are forage (for age); (12) A rope twenty yards long; (13) The blast of a horn; (14) Butchers, because they are always stealing (steeling) their own knives and other tools.

THINGS DIFFICULT TO SAY

We all know the curious sentence with many saws in it that we were asked to say when we first went to school: "Of all the saws that ever I saw I never saw a saw to saw like this saw was to saw." That is quite easy to say, but there are many other sentences with the same word or syllable or sound that are so hard to say, and especially to say several times in quick succession, that they have obtained the apt name of tongue-twisters. "Truly rural" seems quite a simple expression, and yet there are very few people who can say it quickly six times running without twisting it into something like toore-looral.

Here is a tongue-twister in the form of a verse:

Oliver Oglethorpe ogled an owl and oyster;
Did Oliver Oglethorpe ogle an owl and oyster?
If Oliver Oglethorpe ogled an owl and oyster,
Where are the owl and oyster Oliver Oglethorpe ogled?

Perhaps even more difficult to repeat than either of these is a verse in which the sound of q occurs in almost every word.

Quixote Quicksight quizzed a queerish quidbox;
Did Quixote Quicksight quiz a queerish quidbox?
If Quixote Quicksight quizzed a queerish quidbox,
Where's the queerish quidbox Quixote Quicksight quizzed?

The sound of c, too, mixed up with the sound of cr, is difficult to repeat over and over again in a sentence. Here is a sentence combining these sounds:

Captain Crackskull cracked a catchpoll's cockscomb;
Did Captain Crackskull crack a catchpoll's cockscomb?
If Captain Crackskull cracked a catchpoll's cockscomb,
Where's the catchpoll's cockscomb Captain Crackskull cracked?

A very good tongue-twister is the verse about the sea-shells:

She sells sea-shells on the sea-shore;

The shells she sells are sea-shells I'm sure.
So if she sells sea-shells on the sea-shore;
Then I'm sure she sells sea-shore shells.

Here is a prose tongue-twister which should be repeated very rapidly:

How much wood would a woodchuck chuck if a woodchuck could chuck wood? If a woodchuck could chuck wood, the wood that a woodchuck would chuck is the wood that a woodchuck could chuck, if the woodchuck that could chuck wood would chuck, or a woodchuck could chuck wood.

A shorter but scarcely less difficult tongue-twister is this sentence of only six words:

Seven Severn salmon swallowing several shrimps.

Here is a series of sentences that Dr. Moberly, headmaster of Winchester School, and afterwards Bishop of Salisbury, used to make his boys read, placing the emphasis on the right words. They are all perfectly correct but take a good deal of examination before the sense can be understood in each case:

I saw that C saw.
C saw that I saw.
I saw that that that C saw was so.
C saw that, that that that I saw was so.
I saw that, that that that that C saw was so.
C saw that that, that that that that I saw was so.
I saw that that, that that that that that C saw was so.

It is very amusing to try to repeat this:

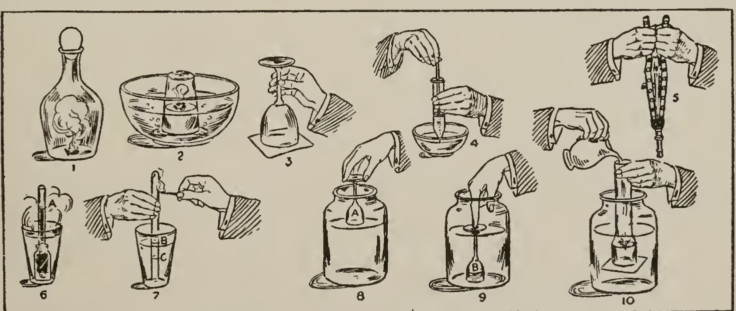
Mrs. Biggar had a baby. Which was the bigger? The baby was a little Biggar! Which was the bigger, Mrs. Biggar or the baby? Mr. Biggar was father Biggar! Mr. Biggar died; was the baby then bigger than Mrs. Biggar? No, for the baby was fatherless!

MYSTERY AND MAGIC

Simple experiments with air and water

We can learn a great deal of science from the most familiar objects in our homes, and an interesting half-hour may be spent in performing simple experiments that will teach us much that we ought to know.

First of all, we can perform an experiment that will show us how the air, that is invisible and does not seem to have any weight, is actually pressing down upon us and upon



Easy experiments that can be tried in every home everything on the earth's surface. We take a wide-necked bottle, and also prepare a hard-boiled egg to help us in our experiment by carefully removing all the shell.

Now we put into the bottle a piece of lighted paper, and, after a second or two, place the egg in the neck of the bottle as though it were the stopper. The egg will, of course, remain there just as if it were in an egg-cup. At least, that is what some of us would expect. But if we watch the hard-boiled egg we shall see, after a time, that it is gradually going down the neck of the bottle as though it were being sucked in. Then, suddenly, it will enter the bottle with a loud noise. What is the explanation of this? It is very simple. The burning paper heated and expanded the air in the bottle, and some of it was driven out through the opening at the neck. Then the egg was placed in the neck and the opening was stopped up. Presently the air in the bottle cooled, and, as it lost its heat, it contracted, or filled less space, so that there was a partial vacuum in the bottle, and the air outside pressing upon the egg drove it into the bottle. The report was caused by the outside air rushing in as soon as the falling of the egg opened the neck once more.

There is another simple experiment which shows clearly the pressure of the atmosphere. Take a basin of water, and on the surface of the water let a cork float. Now place on the cork a piece of lighted paper, and over these invert an empty glass, pressing it down gently into the water. Bubbles will be seen to come from under the glass. This is the air being driven out owing to the fact that the heat from the lighted paper has expanded the air, and the glass will not hold it all. A few moments after, the water is seen to rise in the tumbler. The cause of this is that when the paper is burned out the air cools again, and as it does not now fill the glass the pressure of the air on the surface of the water drives it up into the tumbler.

Still another experiment will prove that the air exercises a pressure, not only downwards, but upwards as well. We take a wine-glass, and fill it carefully up to the brim with water. Then take a thin sheet of paper, and place it on top, so that it touches both the surface of the water and the rim of the glass. Now, holding the paper carefully in position, we turn the glass of water upside down, and the water will remain in the glass apparently suspended. Of course, it is not really suspended, but the air is pressing it up into the glass. The air must not be allowed to get into the glass while we are inverting it, or the water will come out; and as any carelessness will result in an accident, it is always wise to perform the experiment over a basin.

If we should like another experiment to prove the downward pressure of the air, we can use our basin of water again, and take a small ear-syringe such as is found in every house. We fill it with water, and invert it with the point in the water in the basin. Now we press down the rod and empty the syringe. But directly we pull up the rod again the water rushes up and fills the syringe. The reason of this is that the pressure of the air all over the surface of the water in the basin drives the water up into the syringe.

An interesting experiment, this time with a pair of ordinary domestic bellows, proves that the pressure of the atmosphere is exerted, not only above and below, but sideways and in all directions. Having blown all the air out, we completely stop up the nozzle and the vent-hole with corks, and then, if the bellows are in proper order and are air-tight, no boy will be able to open them, no matter in what position they may be held. The air outside pressing equally on all sides holds the bellows together.

All bodies, solids, liquids, and gases alike, when heated expand—that is, fill more space—and two simple experiments will show this clearly in the case of liquids and gases. We take a small bottle, fill it with some colored liquid, such as water in which a little coloring has been dropped, and cork it up. But we must see that the cork is pierced, and a piece of glass tube, open at both ends, inserted. Now, if we plunge the bottle into a vessel of warm water, as seen in picture 6, the colored liquid will be seen to rise in the tube to A. This is because the warm water in which the bottle was plunged has heated the liquid in the bottle, and caused it to expand and overflow into the tube.

To show that gases expand we must use a glass tube closed at one end. We take the tube, which is, of course, full of the gas that we call air, and put it into a tumbler of water, as shown in picture 7. The water rises to a certain point, B. Now we hold a lighted taper to the upper part of the glass tube, and, after a second or two, the water descends in the tube from B to C. This is because the heat expanded the air in the tube, and as it wanted more room drove some of the water out.

Another experiment with a wine-glass and a jar of water will show that gases, such as the atmosphere, possess the property of compressibility—that is, they can be pressed into smaller space. We take the wine-glass and invert it on the surface of the water. The glass is full of air, which occupies the whole of the space A in picture 8. Now we press the glass down to the bottom of the jar, and we see, as in picture 9, that some water has risen in the glass, and the air that formerly occupied the whole glass now fills only the space B. As we gradually lift the glass out of the jar, we see that the air expands and fills the glass as easily as it was compressed.

There is a simple experiment to show that liquids, like gases, exert a pressure equal in all directions. Take an ordinary lamp chimney and p'ace below the widest opening a piece of cardboard. Hold this against it and plunge the whole into a jar of water. Now remove the hand that held the cardboard, and it will be found to remain in position, the upward pressure of the water holding it against the glass. Now pour water gently into the lamp chimney from above; the card continues in position until the water in the glass reaches the level of the water in the jar. The pressure of water top and bottom being then equal the card will be displaced, and sink to the bottom of the jar by its own weight.

A TRICK TO PLAY WITH A BOOK

This is a trick of a really startling kind, which will puzzle even the wisest man if he does not know it.

You invite someone, the older and wiser the better, to take down any book he pleases from the bookshelves, to open it haphazard, and to choose a word in the first nine lines of any page, and not after the ninth word in the line. He is then to notice the number of the page, and multiply it by 10. To the product he is to add 25 and the number of the line. The result thus obtained is in turn to be multiplied by 10, and the number at which the word stands to be added to the product.

He is then to hand you the book, with a slip of paper on which are written the figures last obtained. After thinking for a few moments you open the book and read out the word chosen.

To obtain this surprising result, all that you have to do is to subtract in your mind 250 from the amount given you on the slip of paper handed to you.

The last figure of the answer will give you the number at which the word stands in the line, the last but one the number of the line, and the remaining figures the number of the page.

Suppose, for instance, that the person choosing the word had happened to choose the fifth word in the ninth line of the eighty-fourth page. In such case the process would be as follows:

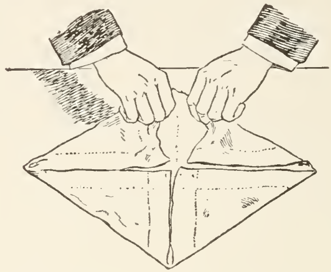
$$84 \times 10 = 840$$
$$840 + 25 + 9 = 874$$
$$874 \times 10 = 8740$$
$$8740 + 5 = 8745$$
$$8745 - 250 = 8495$$

And 8495, dissected as explained, gives 84, 9, 5, being the three clues necessary to the discovery of the word.

THE DISAPPEARING DIME

This is a capital trick. Two things only are wanted for it—a handkerchief spread out upon the table, and a dime laid in the middle of it. The corners of the handkerchief are folded down over the coin, and anyone is permitted to feel that it is still there. And yet, at the conjurer's command, it passes through handkerchief and table, and is found on the floor beneath. The handkerchief is shaken out, and proves to be empty. This trick is good enough to make quite a reputation for the youthful wizard, and yet it is simplicity itself—when you know it!

In the first place we must have two dimes in appearance as nearly alike as possible, and one of these we take an opportunity to drop quietly beforehand under the table at which we propose to perform the trick. The only other thing required is a little pellet of beeswax. This we must knead between the fingers till it is fairly soft, and then press, till needed in another sense, against the back part of our lowest vest button.



To perform the trick, take the wax off the button, and press it against one corner of the handkerchief which you are going to use. Then lay the handkerchief on the table squarely in front of you, with the waxed corner nearest to the right hand. Lay the dime on the center of the handkerchief, or better still, let somebody else do this, to prove that there is "no deception." Then fold down the corners of the handkerchief one by one over the coin, beginning with the waxed corner, and pressing this down a little, so as to make it adhere. This done we ask someone to make sure, by feeling through the handkerchief, that the coin is still there. Each person who does so presses the wax a little closer.

Now comes the exciting moment. "Now, ladies and gentlemen," you say, "I am going to make the dime pass right through the table, and be found upon the floor. If you will all be very quiet, perhaps you will hear it fall." They won't, but they may as well imagine that they do so.

We blow upon the center of the handkerchief saying, "Presto! Pass!"

Then, hooking the first and second fingers of each hand inside the nearer opening of the handkerchief, as shown in the picture, we draw the two corners smartly apart, one in each hand, and shake it out. The coin, adhering to the handkerchief, is drawn into the right hand. "Look under the table, and see whether it has gone through," you say, and while general attention is occupied by looking for and picking up the other coin, you will have ample opportunity to get rid of the one in the hand.

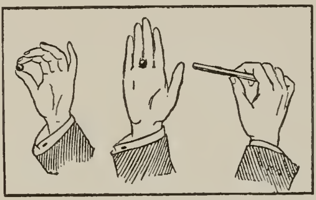
Of course we are not bound to make the coin pass "through the table." If we prefer it we may order it to pass under a candlestick, into a vase on the mantelpiece, or even into somebody's breast-pocket. All that is needful is to place the duplicate dime where we intend that it shall be found, and alter the command accordingly.

Making a ball vanish and reappear

For the performance of this conjuring trick the only apparatus we need is a little ball, light in weight and rather smaller than a marble in size, and a small stick for a wand. We hold the ball up between the thumb and forefinger of our right hand, as shown in the first picture, so that all the spectators may see it clearly. Then we say that we shall place the ball in our left hand, and we proceed to do so; but instead of putting it in the left hand, we skillfully roll the little ball down the right hand, and fix it as shown in the second picture, so that it is supported between the second and third fingers. To do this quickly and successfully needs a little practice, but it is quite possible for any boy or girl to learn the trick in a very short time.

Now we close the left hand as if we were holding the ball in it. Then, still supporting the little ball between the second and third fingers of the right hand, we take up the wand, and, tapping on the knuckles of the closed left hand, we say, "Vanish, little ball!" and instantly we open the hand and show that the ball, which was supposed to be in it, has disappeared.

If we are skillful in performing the trick so far, we shall have no difficulty in continuing it, and, to the astonishment of the spectators, we shall call the little ball back from the inside of the wand. We continue to support the ball between the second and third fingers of the right hand, keeping the back of the hand towards the audience all the time, though, of course, without



How the ball is concealed

appearing to do this purposely. We take the wand in the right hand, as in the third picture, and, holding the other end with the left hand, we call to the ball to come forth from inside the wand. As we speak we work the ball in an instant from its hiding-place, and hold it up once again before the spectators, as in the first picture. Of course, in all such tricks as this we should practice well alone before attempting to give an exhibition before others.

The boy conjurer's joke with his audience

At the end of a series of tricks it is often a source of great amusement to entertain the audience with what schoolboys call a "sell"—a practical joke in the disguise of a conjuring trick. The only apparatus needful is the pencil, and this you can manufacture for yourself. You have merely to change an ordinary pencil in such a way as to make it look like an extraordinary one. For instance, you may paint it in three colors—red, blue, and yellow, successive rings of each color; or, for lack of paint, colored paper may be used—anything, in fact, to give it an unusual appearance.

Having performed a few genuine tricks, you produce the pencil and a blank sheet of paper, inviting the company to examine them. "Now, ladies and gentlemen," you remark, "you notice no doubt, that this is a rather peculiar-looking pencil. But its appearance is the least of its peculiarities. In point of fact, it is an electric pencil. At present, you see, it writes plain black like any other pencil." Here you make a few marks with it and proceed: "But if I electrify it a little, it will write red, blue, or yellow—in fact, any color, just as I please. What color will you have? Choose for yourselves." "Red," we will suppose is the reply. You gravely breathe upon the pencil, rub it upon your coat-sleeve, and proceed to write the word "red" in bold letters. "There it is, you see—red. If you had asked for blue or yellow, it would have been just the same." Which nobody can deny.

The success of the trick rests on the fact that the audience have been prepared, by seeing sundry surprising things, to expect something equally surprising. If the trick were offered offhand, without such preparation, some of the audience would probably see through the joke; but if it is led up to in a proper manner, they will hardly ever do so.

A GOOD CONJURING TRICK WITH NUTS

There is an excellent conjuring trick that can be performed with very little preparation or apparatus, and if it is practiced once or twice until skill is acquired, it will greatly mystify the spectators.

We hand round us for the inspection of the audience an empty dessert plate and a clean pocket-handkerchief. These can be handled by anyone who likes to prove that they have no secret pockets or recesses. We now place the empty plate on the table, spread over it the pocket-handkerchief, and then, after making a few mysterious passes with the hand or a wand, we raise the handkerchief and shake out of it upon the plate a number of sweetmeats or nuts.

This is the explanation of the trick. We make a small triangular bag, as shown in the first picture, by sewing

The trick bag

together two triangular pieces of linen or calico, and in the two hems on each side of the opening we sew straight pieces of watch-spring, taking care that in each case the spring goes the whole length of the hem. These springs, if flat, will close the opening of the bag, and keep it closed unless force is used to open it. A pin, bent to a hook, is put through the apex of the bag.

Nuts or sweetmeats are now placed in the bag, and the spring closes the mouth, so that when the bag is suspended they will not fall out. Having prepared the bag in this way, we hang it by the hooked pin on the side of the table that is away from the spectators, this being done, of course, in advance, before they sit down, so that they know nothing about it.

After showing the empty plate to the audience, we place it on the table near the edge where the bag is suspended, and in spreading the handkerchief over it we see that part of it hangs over the edge of the table where the hooked pin is. Then in picking up the handkerchief we dexterously pick up with it the bag. The handkerchief falling around so as to hide the bag. The rest of the trick is simple. We shake the handkerchief with a few vigorous jerks and the impact of the nuts or sweets parts the springs, which are not very stiff, and allows the objects to fall out on the plate. The bag can then be skillfully dropped behind the table, which should, of course, have a thick cloth on it, reaching to the floor, to effectively hide the back. There are few conjuring tricks so easy to perform, and yet so surprising in their effects.

GAMES AND AMUSEMENTS

THE "ALICE IN WONDERLAND" TUB

ALL boys and girls know "Alice in Wonderland," and there is a good Alice game that we can play.

We prepare a shallow tub and decorate it, inside and out, with green muslin and pretty wreaths of ivy. Boys will easily put together a lattice made of wire, one, perhaps, with four large squares or oblongs; the outer circle should be of the same size as the tub. A very pretty cover is made when this lattice is decorated with greenery.

Then lovers of "Alice in Wonderland" collect as many as they can of the people in the book—white rabbits, the Mad Hatter, the Dormouse, Bill, the Lizard, and a host of other characters can easily be made up by clever boys and girls. They should be wrapped carefully in prettily tinted papers, and the packets should be tied with ribbons or tapes to match, leaving a long, trailing end. All the parcels should now be placed carefully in the tub, in such a way that the ends of ribbon can be drawn through one of the openings in the cover. Then, when pulled by a pair of eager hands, the ribbon brings out with it a package one longs to open. No packet must be opened, however, until the magic tub is empty.

Who will get the White Rabbit, the Black Kitten, or the dear, sleepy Dormouse? How delightful to find a lobster or a walrus, or one of the poor little oysters! A little pig may be in one parcel; a pepper-pot in the next. There is really no end to the number of delightful people and things that may be popped into the Lewis Carroll lucky tub. But the packages may only be *felt* by those who take possession of them, they are not to be opened until a signal is given, and even then they may be opened only privately—just a private peep.

Everybody then scampers to a seat and waits for more fun. A clever grown-up somebody takes a chair in the middle of the room and begins telling, quickly and cleverly, the story of "Alice in Wonderland," and when the moment comes for the dear, fussy White Rabbit to be mentioned a pause is made, the storyteller strikes a gong, and before sixty seconds have passed the child with the White Rabbit must have loosened the coverings that conceal him, run to the side of the storyteller, and hold him up for general observation, pronouncing his name. Sometime three or four people must run at the same moment; what would the Mad Hatter, the March Hare, the Dormouse, and Alice do without the big teapot or the wonderful watch?

Each boy or girl who succeeds in getting to the center of the room at the right moment takes a chocolate from a box placed close to the story-teller, and returns to his or her place until wanted again. This time the concealing papers need not cover the treasure drawn from the lucky tub; it may be placed on the floor of the owner's feet, so that its beauties may be properly noted. Then, when the story comes to an end a big march past to music takes place, and a boy, wearing the Mad Hatter's Hat, makes a fine leader of the procession.

GAMES TO BE PLAYED IN THE NURSERY

Hunt the slipper

ALL the players but one—"cobblers," as they are called—sit on the floor in a circle a few inches apart. Then the customer comes and says: "Please, I want this old slipper mended. I will call for it in ten minutes."

She hands one of the cobblers an old slipper, and turns away. When she has counted up to ten, she comes back, but is told the slipper is not ready.

"I must have it," says the customer.

"Then you must find it," all the cobblers reply.

At that the search begins. Each cobbler passes the slipper on to his or her neighbor, hiding it from sight as much as possible; but should the seeker spy it and call out the name of the cobbler who has got it, that cobbler must take her place, and bring it to be mended again. The slipper must not stop in one place, but must keep passing round the circle, either one way or the other.

The garden gate

The garden fence is made by all the players, except one, holding each other's hands, standing in a big ring. In the middle stands the single player, while the rest dance round her three times. Then they stand still while she sings:

"Open wide the garden gate, the garden gate, the garden gate,
Open wide the garden gate and let me through."

But the "fence," as the ring is called, only answers, as it dances round again:

"Get the key of the garden gate, the garden gate, the garden gate,
Get the key of the garden gate and let yourself through."

Then the poor prisoner cries:

"I've lost the key of the garden gate, so what am I to do?"

Still dancing, the others sing:

"Then you may stop, may stop all night within the gate,
Until you're strong enough, you know, to break a way through."

At this the prisoner runs between two of the boys and girls—the "palings" of the fence—and if, by pushing, she can make them unclasp hands, one of them takes her place in the middle and the game begins again.

Hold fast! let go!

You must listen to what is said in this game, and be careful to do exactly the opposite. Four players stand up, and each takes hold of one corner of a square sheet of paper or a handkerchief. A fifth player calls out: "Hold fast!" and anyone who does not let go will be out; while, if the order is "Let go!" those who *fail to hold fast* will be out. The orders must be given rapidly, one after another, and someone is sure to make a mistake, but the last to do so, of course, is the winner.

Puss in the corner

In this game all the children pretend to be mice, except one, who is the puss. "Puss" stands in the middle of the room. Each mouse stands in a corner. While there puss cannot touch them, but when they run across the room to change corners with one another she may capture any she can. No mouse should venture from a corner until she has made signs to another mouse with whom she would like to change houses, or she may find herself half-way across the room with no corner to run to. The mouse that is caught must take the place of puss.

Blind man's buff

Those who want to make a great noise will have a chance now. One player is taken into the middle of the room, where a handkerchief is tied over his eyes. He is then turned round three times and told to catch whom he can. The other players run to and fro, passing as near to him as they dare, while the blindman rushes in all directions, clutching at those who seem nearest. When he succeeds in catching someone, he must guess who it is, and, if correct, the person caught must be blindfolded in his place. If he cannot guess, he must leave go and try again.

Wolf

The "wolf" is a player who creeps away to one side of the nursery, and hides behind chairs and tables or boxes. The "sheep" all huddle up at one end of the room, and the shepherd stands at the other. Presently he calls out to the sheep to "come home, for the night is falling."

"We are afraid of the wolf," answer the sheep.

"The wolf is away!" cries the shepherd.

Then the sheep all run across. Out jumps the wolf and catches whom he can. The game lasts till there are no sheep left to be caught.

Bingo

The players join hands in a ring, with one of their number, who is called the "miller," in the center. Then all, still holding hands, dance round and sing:

"The miller's mill dog lay at the mill
door,
And his name was little Bingo:
B with an I, I with an N, N with a G,
G with an O,
And his name was little Bingo."

Then as they stand still again the miller cries out "B" and points at one of the players in the ring, who must say "I," the next to her "N," and so on, until the little dog's name is spelled. The first player to say the wrong letter has to change places with the miller.

Feather and fans

A fluffy feather out of any cushion will do for this game, and if there are not enough fans to go round, stiff pieces of paper or thin card will do quite as well. Draw a line across the nursery floor, and let half the number of players be on one side, and half the number on the other. When all are ready, toss the feather into the air and keep it up with the fans. No players must leave their side of the line, but should do their best to stop the feather sailing across it. Those in whose country it falls at last lose the game. Of course the feather, while in flight, must not be touched.

GAMES TO PLAY BY THE FIRE

Word-making

NEAR the top of a slip of paper each player writes down a word given out by the leader of the company. Then all start to make a list below it of other words, spelled from the letters it contains—and these letters only. When the leader says that time is up (about ten minutes should be allowed), the lists are added up, and the player who has made the largest number of words is the winner. It is not necessary to choose a very long word, for it is surprising how many words may be made from the letters contained in any word of ordinary length. For example, from the word "animal" we can get: am, nail, main, lain, and so on.

Magic answers

This is a game in which two of the players form a plan between themselves to puzzle the rest. One of these two leaves the room, while his partner remains behind to choose with the rest of the company some object to be guessed.

The one outside is then recalled and questioned by his accomplice as to what this object is. Several things are touched. "Is it this?" "Is it this?" he is asked. To every inquiry he answers "No," until something is mentioned that has four legs, and as he and his friend have previously arranged that such an article shall not be referred to till just before the real object is named, he knows that the next question may be answered with a "Yes."

Proverbs

While one of the players is out of the room, the rest think of a proverb. It should contain at least as many words as there are players.

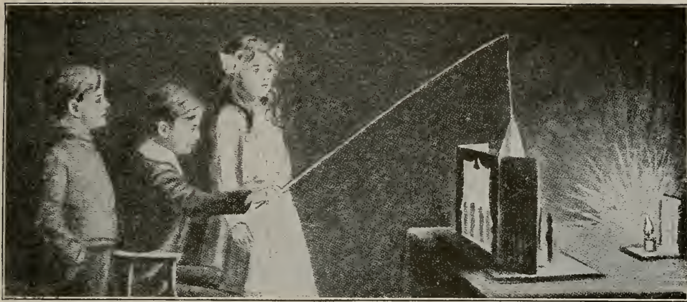
The boy or girl who has been sent out is now called back, and begins the game by asking the first in the row a question. This question may be of any kind, but the answer to it must contain the first word of the proverb. The next is then questioned, and replies with the second word, wrapped up, as it were, in the answer.

Supposing the proverb to be, "It is never too late to mend," and the first question is, "How many apples do you eat in a day?" the answer might be, "As it is not wise to eat too much of anything, there are some days when I don't eat apples at all." The word "it" is not easy to notice in this sentence. But it would be more difficult to hide the last word in the proverb.

Let us take as a question, for example, "Are you fond of reading?" The answer might be, "Yes; but I tore the pages of my favorite book, and must mend them before I can go on with the story." If you wish to puzzle the questioner you should not let your word begin or end the sentence.

General post

All the players sit round the room in a large circle, and one, who is blindfold, stands in the middle. Each player takes the name of a town, and the leading player makes a list of these, from which he calls out now and then, thus: "The Post is going from Chicago to Denver," choosing "towns" on opposite sides of the circle. "Chicago" and "Denver" jump up and slip across to each other's seat, the blindman doing his best to catch one of them as they pass. When several towns have changed places, and the blindman has failed to make a prisoner, the leader cries out "General Post," when all must jump up and cross over to opposite sides. In the hurry and confusion the blindman is sure to catch someone, who takes his place while he becomes one of the towns.

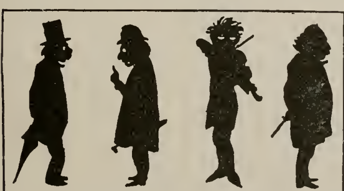


A LITTLE SHADOW THEATER

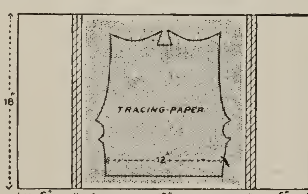
BY means of scissors, paste, cardboard, paper, and a piece of wood, any bright boy or girl can make an amusing toy that will provide plenty of fun for a Christmas or New Year party, and will be equally interesting for grown-ups and for children. The toy is a shadow puzzle game, and is made in this way. Take some stiff cardboard, and cut out two pieces 15 inches high by 6 inches wide. Then cut another piece 15 inches high and 18 inches wide, and from the center of this larger piece cut out a space about 12 inches high and 12 inches wide, so that what is left will look very much like the wings and curtain of a theater. Now take two strips of gummed paper, and fasten the two narrow pieces of card to the larger piece, one on each side, so that the paper will form hinges, and the side pieces can be turned at right angles to the middle card. Strips of linen pasted or gummed on to the card make even better hinges than the gummed paper.

To make this screen frame neat, cover one side of it with black paper—not the side on which the linen or paper strips are pasted. Then, turning the screen over, paste over the opening which we have cut out a piece of ordinary semi-transparent tracing paper. The paper should be as white as possible. The screen is now ready, and it may be put aside while we make the rest of the toy.

Cut out four figures in stiff cardboard, each about three inches high, and these should be, if possible, rather fantastic and humorous, as that will add to the fun of the game. Any kind of upright figures will do, and may be copied from books, but if there is any difficulty about drawing men, four



Little men for the shadow theater



The framework of the theater

upright pieces of card may be cut into any kind of irregular shapes, and will serve for the purpose of the game.

A piece of wood, 12 inches long by about 6 or 7 inches wide and ¾ of an inch thick, is wanted for a stand for these figures, and running the whole length of the board, cut six grooves at regular intervals, just wide and deep enough to hold the figures upright when they are placed in these grooves.

Now take some stiff paper an
make four extinguishers, by rolling u
the paper in the form of a cone, an
cutting the opening evenly all roun
Then sew a little ring in the top o
each. The extinguishers should b
about 4 inches high and 2 inches i
diameter at the bottom.

Next get a thin stick about 2
2½ feet long, and in the end put
nail or drawing-pin, and to this fast
a straight piece of wire about 12 inch
long with the end turned up slight
to form a hook. The wire should
stout enough to remain stiff a
straight. All that is necessary n
for the game is an ordinary candl
a candlestick.

Any number of people may pla
puzzle shadows. Stand the scree
the table, with the wings folde
right angles, as shown in the pic
and put a lighted candle some dist
at the back of it. One who doe
take part in the game acts as m
of ceremonies. He puts the w
stand between the screen an
candle, and then places each o
four figures in a groove.

All lights in the room except the candle are turned out. The first player now takes his place before the screen, and he must on no account look round or over it to see what is behind. Hooking the wire holder into the ring of one of the extinguishers, he lifts this over the top of the screen, and guided only by the shadows of the figures and extinguisher on the paper front of the screen, he tries to put the extinguisher over one of the figures. So long as the shadow of the extinguisher is above the shadows of the figures it may be moved about in any direction, but directly it touches or begins to cover the shadow of a figure it must be let down at once. The holder is gently unhooked, and another

catch fire.

YOU MUSTN'T LAUGH!

All sit in a row round the fire and look solemn. Then the first player says: "Haw-haw!" which is repeated all down the line, one after another. Those who cannot do this without laughing afterwards are declared out, and the game begins again.

AMUSING GAMES FOR HALLOWEEN

HALLOWEEN, or All Hallows' Eve, is a festival that has long been observed, particularly in Scotland, and although many of the customs associated with the season are superstitious, yet there are also some interesting games which boys and girls have played for generations on Halloween, or the last night in October.

Ducking for apples in a tub of water · Cutting down the apple · The apples captured from the water

Some of these historic games are illustrated on this page. One of the most popular is that of ducking for apples. A large tub or bath is nearly filled with water, and a number of apples are set floating on the water. The boys and girls then gather round, and take it in turn to duck their heads into the water, trying at each duck to seize an apple in their teeth.

Sometimes the apples chosen are provided with stalks, and sometimes apples without stalks are selected. The greatest fun is to have some of each kind. Of course, those with stalks are captured first, and then the excitement increases. Small apples can be sucked up into the mouth, but the larger ones have to be chased to the bottom or side of the bath, and there seized with the teeth.

Another game is to suspend an apple from the ceiling or chandelier by a string, and for the boys and girls then to take it in turns to try to cut the string. They have to be blindfolded, and are placed some distance from the apple. Then they take three steps forward, scissors in hand, and make a cutting motion where they think the string is. It is great fun to see the many amusing and fruitless attempts that are made before anyone succeeds in cutting down the apple.

These pictures show a boy and girl playing the Halloween game of dropping a fork to pick up an apple

Still another game with apples is to place several of them in a tub or bath of water, and to put this near the back of a chair. Then the boys and girls take it in turn to stand or kneel on the chair, and to drop a kitchen fork into the tub, trying to spear an apple. If the player succeeds, the apple is his. Sometimes the fork is held by the handle in the mouth, and allowed to drop from there into the tub. This makes it harder to spike the apples. We must, of course, be careful not to overbalance the chair.

Instead of the tub being nearly full of water and having apples floating in it, it is sometimes left dry, and in it are placed an apple, a potato, a carrot, and a turnip. The boys and girls then drop the fork and see which they can manage to secure. The apple is the most sought after, and the turnip is regarded as the least desirable.

In addition to these games, there are many other customs practiced on All Hallows' Eve which are interesting as being survivals of a past age. For instance, nuts are placed in the fire, and according to the order and the manner in which they crack or jump out, so certain things are imagined as to what will happen in the future. Very few people believe in such foolish superstitions nowadays, but there is much amusement in watching the nuts and seeing how they happen to fall and which crack first.

Literature is full of references to Halloween. The most famous is perhaps Burns's poem, beginning "Among the bonnie winding banks." Goldsmith, in his "Vicar of Wakefield," refers to the custom of cracking nuts on Halloween.

GOOD GAMES FOR A CHRISTMAS PARTY

To make a Christmas party a thorough success there is nothing like having plenty of variety in the games. There is no chance then of the boys and girls getting tired because some of the games are more or less alike.

A very good game for a large or small party is that of "guessing with the wooden spoons." One of the party—a girl, for instance—is blindfolded, and sits upon a chair. She is then given two large wooden spoons, such as are in common use in every kitchen. One after another the other boys and girls come up to the blindfolded sitter and stand or kneel before her, and she has to guess who each one is by simply feeling him or her with the wooden spoons, as shown in the picture on this page.

Guessing with the wooden spoons

The task is very much more difficult than it looks, and there is great fun as the spoons go over the face and body in the attempt of the blindfolded player to discover the identity of the other. It is not easy for the one who is being touched with the spoons to abstain from laughing, especially when all the other players are equally amused.

Of course, any outburst of laughter when the spoons are going over our face would disclose our identity, so we must keep perfect silence. When anyone's identity is guessed, he has to be blindfolded and must take the spoons. We must be careful when using the spoons to touch another player with them quite lightly, so as not to hurt him; and any player who wears glasses should remove them before going to be felt with the spoons.

Another good game for a Christmas party is that of blowing the egg. Two pieces of cotton or tape are stretched across the carpet in a straight line about two feet apart. Then an ordinary hens' egg—not too large—which has been prepared beforehand by being blown—that is, having the contents removed without cracking the shell—is laid exactly midway between the tape lines. A girl player then makes a little paper fan out of half a sheet of notepaper, and kneels down on one side of the tapes, and a boy kneels down on the other. The girl then has to try to fan the egg-shell across the tape on the boy's side, and he has to try to blow the shell back across the tape on the girl's side. The one who first drives the egg across the partner's line three times wins the contest. Nothing must be used by the girl but the paper fan or her hand; and the boy, on his part, must simply blow with his mouth. If more convenient, a large dining-table may be used instead of the floor.

Blowing the egg across the line

Fanning the egg with a paper fan

A CHRISTMAS TREE FOR THE BIRDS

Christmas would not be Christmas without a Christmas-tree. But have you ever thought when you have been enjoying yourself, that the winter, which brings lots of fun for all of us, is a very uncomfortable time for the poor things who do not have warm homes?

Perhaps, on some cold morning, you have looked out of your window, and have watched the birds flying about among the bare branches of the trees in the garden, searching the ground in the hope that some kind person has thrown out a few crumbs for them?

Have you not sometimes wished there was a Santa Claus to bring a tree full of good things for the birds? Perhaps it never occurred to you that *you* might be the birds' Santa Claus? Well, we are going to see how to make a Christmas-tree for those poor little mites.

First, we must get a small tree that can be put into a pot. Probably we shall find one in the garden, and will be allowed to dig it up. If not, we can buy one about Christmas-time for a few cents.

When we have our tree planted in a large flower-pot, we must get some small baskets—the tiny ones that sweets are sold in will do splendidly—and tie these baskets to the branches of the tree. We can put all sorts of things into these baskets—bread-crumbs, nuts, little pieces of crust or toast from the breakfast table, or some of the seeds that are given to tame birds and little pieces of suet.

A Christmas tree for the birds

We can make our Christmas-tree look very pretty with some bright pieces of cloth and ribbon, or colored paper made into little bags to hold bread-crumbs, and then, when it is finished, we must put it out in the garden or on the window-ledge of our own room. At first the birds will not understand, because nobody has ever taken the trouble to make a Christmas-tree for them before, and perhaps they will think it is some sort of trap. But presently some of the bravest ones will come. Then we shall see them perch on the branches, and look round in every direction to see if there is any danger.

We can watch them through the window, and they will not be frightened if we do not move. As long as we keep quite still, they will not think we are going to hurt them. In a little time the birds will put their tiny heads in the baskets, and give a little twitter of delight when they find the good things there. Other birds will be watching them from the trees, and when these see that the braver ones have not been hurt, they too will come. When the tree has been out a little while, we shall see perhaps forty or fifty birds of all sorts fluttering round it.

When they have eaten everything, we can refill the baskets.

GARDEN GAMES

TOM Tiddler's Ground is a good game when there are at least three players. One is told off to be Tom Tiddler, and his ground is the lawn, or the path, or any other part of the garden that may be specially marked off. Tom Tiddler gets on to his ground, and, shutting his eyes as he stands, pretends to be asleep, and the other players venture upon the ground, singing:

> Here I am on Tom Tiddler's ground,
> Picking up gold and silver.

As Tom Tiddler makes no sign of being awake, the other players go farther and farther on to his ground, and then suddenly Tom Tiddler makes a dash, and tries to touch one of the others. If he succeeds, the one touched becomes Tom Tiddler. If he does not, and both of the other players get quite safely off his ground, he must continue to be Tom Tiddler.

Games of touch

Cross Touch is a good game for three players, and provides plenty of exciting play and healthy exercise. One player is "He," and has to call out the name of another player, and then to run after him.

The third player tries to run between the hunter and the hunted, and if he succeeds in doing so, "He," has to run after him and try to touch him. But if the second player manages to run between the others, then he draws off "He" after himself. The more frequently the player runs between hunter and hunted, the more exciting and varied the game becomes.

Touch Wood is another game that can be played by three players. One is "He," and runs after the others, trying to touch either of them. But if a player touches wood—a tree-trunk, or fence, or wooden shed, or anything of that kind—he cannot be touched by "He." Of course, those who are being pursued must not touch wood too often, nor must they remain touching it for very long, or the game will get slow. What "He" has to do is to try to drive them where there is no wood to touch.

Follow my leader

If the garden is a large one, Follow My Leader can be played with a good deal of fun. One is chosen as leader, and wherever he leads the others must follow, whatever he does they must do, even to a motion of the arm, or leg, or head. The first one to fail in following the leader loses the game. Of course, the leader must be careful to do nothing that will mean danger for a younger player, and he must be very careful not to go too near flower-beds, or to do anything that will result in damage to flowers.

Field golf

We are going to play golf in a new way, which is quite simple, but very good fun. Choose a starting-point in a large field and dig there a very small hole. One hundred steps away, in a straight line from this, we make another hole in the ground. Then, at the end of another hundred steps, another hole, and so on until we have gone round the field and are back at the starting-point. These holes mark our golf-course. Each player is armed with a club-ended stick and a small, hard indiarubber ball. The game is to strike these balls round the course, knocking them into each hole as it is reached, and the one who does this and gets round to the starting point with the fewest strokes wins. Each player, of course, only hits his own ball. The starting-place should also be used as the last hole.

Tug of war

A strong, long rope is laid on the ground across a chalk line. The players are then divided into two parties, one side taking up the rope on one side of the line and the other the opposite side. At a given signal they pull against each other with might and main, and the side that draws the enemy over the line are the victors.

Flags

A long straight line is chalked on the grass, and the party of players is divided into two equal numbers, or sides. Each side then goes into its own "country," the line stretching between them. Every player must have a small United States flag to stick down in the turf or lay down on the grass, a few yards inside his line, a handkerchief, a cap, or a scarf; these may be the "flags." At a given signal one side rushes across the line to try to capture the enemy's flags. Those who succeed must be allowed to return to their country, but any caught before securing a flag are prisoners. It is then the other side's turn to cross the line, and their prisoners (if any) must help to capture the lost flags and those belonging to the enemy. No player must take more than one flag at each attack, and the side that is first to lose its flags is defeated.

Bounce about

Two players, with two marbles, play this game. The larger the marbles the better. One boy throws his marble down. If his companion can hit it with his own, he wins 10 marks, and has the right to try again, aiming from the spot at which his marble stops. He may keep on till he misses, when the other player takes a turn. A certain number should be fixed upon —say, 100—and the player whose marks reach this first will be the winner. Sometimes this game is played with smooth pebbles.

Catch-ball

Any number of players can join in this game. It simply consists of tossing the ball from one to another, but it may be made more exciting if no special plan is followed as to whom the ball is to be thrown next. This keeps everyone on the alert, and a very good trick is to look at some other player than the one you intend to throw to. This nearly always leads to a slip on the part of the catcher.

Steeplechase

This is hard work as well as good play. Before starting, a certain point is fixed upon at some distance, with fences and ditches and hedges and brooks in between. Then the word "Off!" is given, and the players race away to see who can get there first. In such a race it is not certain that the fastest runner will win, for the boy who knows how to get over a difficulty stands a good chance.

The traveler and the wolves

The smallest boy or the slowest runner is the traveler, and the traveler has to get to his journey's end without being caught. The rest of the players are the wolves. Before setting out on his journey, the traveler is given as many tennis-balls as there are wolves, and, of course, there should not be more than four or five, or he will have too much to carry. When he has got some distance away, the wolves roar out that they are coming, and the race begins. When the traveler finds a wolf overtaking him, he throws out one of the balls, which the wolf must secure before he can take up the race again. Of course, the traveler's object should be to throw the ball in a way that will lead the wolf from the direct path. Thus, he should never throw it in front, or the swifter runner will pass him to secure it, and then merely wait for him to come up. Knowing what the traveler is going to do, the wolves will probably spread out a little to either side in the hope of stopping the balls more quickly. Therefore, the traveler should do his best to find out where the nearest wolf is, and the more skill he shows in managing the balls the greater will be his chance of escape. Above all, he should not throw them away too soon.

If the chances against him are very great at the start, he might be provided with more balls than there are wolves. Of course, a distant spot should be chosen as a goal.

Leap-ball

This game, which can be played out of doors, is also suitable for a large, clear room. We attach an ordinary indiarubber or tennis ball to a piece of string. The best way to do this is to put the ball in a net and fix the string to the net. Then one player takes the other end of the string and swings the ball round and round on the ground in a circle. The other players stand round in a circle, and as the ball comes round and round each player must jump so that the ball goes under his feet and does not touch him. Any player who is touched must take his place in the center and have a turn at swinging the ball while the others jump.

Cross-ball

Cross-ball should be played by two players standing two or three yards apart. They should start with two balls, and should each toss at the same time so that the balls pass in mid-air. It requires quickness of sight and hand to keep this up, but a little practice will make it easy, and by-and-by a third ball may be added, when the effect is very pretty.

Chestnuts, or any small round objects that are not heavy, or too hard, are better for this game than balls, as they are quickly and easily handled. If the players count aloud as they throw, their actions will become more regular, and slips less frequent.

Fives

This is a game for two or four players. Draw on a flat brick wall a long chalk line, three feet six inches above the ground, and another one along the ground, ten feet from the foot of the wall. Then across each end of this last line, which should be about ten feet in length; draw another at right angles to it, and connecting it with the wall. These lines are to show where the ball is to bounce.

The players divide into two parties —we will call them A and B. A throws the ball against the wall, where it must strike above the chalk line, and when, on springing back, it bounces from the ground, B must strike it with his open hand, sending it against the wall again. Then comes A's turn to hit it on the bounce, and this is kept up, turn by turn, until someone makes a slip.

If the ball strikes beneath the chalk line, or rebounds *outside* the ground-lines, the side that did *not* make this mistake counts 1 to itself. The side that first reaches 12 or 24 marks wins, but any number may be chosen as the players decide.

Driving a blindfold team

A very good game to play in a field or playground, or large schoolroom, is that of driving a blindfold team in and out of a line of bottles or tins. We place the bottles in a row, as shown in the picture, taking care that there is room between any two bottles for two boys or girls to walk abreast. Then, having blindfolded the horses, the driver ties the reins to their arms, and drives them in and out of the bottles, turning the horses alternately to the right and to the left, until they have passed through the whole line.

For every bottle that is knocked over or touched by the horses in their passage, one mark is counted against the team. When one team has driven over the course, another takes a turn, and so on, until all the teams have been through. Then the team that has the lowest score wins the game.

A successful blindfold team

The reins are tied on the outer arms of the team, and the only guidance the blindfolded horses have as to where they shall go, and how they shall avoid knocking over the bottles, is by the pull to right or left given by the driver. It is therefore essential for success in a race that the driver should keep a clear head, and give the necessary directions to his team with skill and care.

Egg hat

The caps of the players are laid in a row on the ground at the foot of a wall; they should be tilted a little, so as to make it easier to toss a ball into them. The players then stand in a row at a line about eight steps away, and one of them pitches the ball at the hats. The moment this is done they all scatter, except the boy who owns the hat it has fallen into.

He must take out the ball as quickly as possible and throw it at one of the other players. If it hits him this boy must, in turn, pitch the ball at the hats.

But if the thrower misses him, a small pebble is placed in his cap as a bad mark, and when any player has missed so often that the number of pebbles in his cap equal the number of players, he is made to stand at a short distance while the rest throw the ball at him, each in turn. The game then starts afresh.

A pebble should also be added for every time a player fails to toss the ball into a hat.

overbalance in the course of pushing the matchbox forward we have to start again. Success depends almost entirely upon knack and balance learned in practice, for short, stout boys are sometimes more successful than tall, thin boys. We should bend as low as possible on the right side, keeping the left shoulder and arm well back to counterbalance the forward weight of the right arm.

A somewhat similar trick is shown in the second picture. In this case we bend forward on all fours, and then, raising the right hand, push the matchbox as far as we are able. Here, again, practice makes perfect, and it is astonishing how far we can push the box after we have tried several times. In this trick, knack does not count for so much; we need strength to support ourselves upon the left arm while reaching forth to push the matchbox.

PUSHING THE BOX THE ARM AND LEG STRETCH KICKING THE BOX

THE MATCHBOX ON THE LAWN

Here are three amusing tricks needing no apparatus other than an empty safety matchbox. We make a line upon the ground either with chalk or by stretching a piece of string across; or we can use as the toe-line any line that there may be upon the linoleum or on the carpet. Then stooping down into the position shown in the first picture, and placing the right hand under the knee, we push the matchbox as far as we possibly can, keeping our toes all the time to the marking-line, and taking care not to lose our balance. Of course, if we

Some prefer to close up the left hand when resting upon it, but keeping the hand open and resting upon the palm gives a better support.

In the third trick we have to stretch with our leg and foot. Some line is marked or decided upon on the floor or lawn, and we toe this line. Then we stretch out with our foot as the boy in the picture is doing, and place the matchbox on the ground just beyond where the foot reached. Now, again toeing the line, we take great care not to overbalance, and, stretching the right foot and leg forward, try to kick over the box.

If we succeed we mark the spot by a match, and put the box still farther away. Then, again, we try to kick it over, and so long as we succeed we continue putting it farther and farther from the toe-line, until at last we mark the limit of distance to which we can reach. Other players then take a turn, and it is very exciting to watch the efforts and see who can kick farthest.

GAMES TO PLAY WHEN OUT WALKING

TO MAKE a walk thoroughly interesting and enjoyable, even though it be over an old and familiar route, is quite easy. We merely want to arrange some simple and amusing games that can be played as we walk, and, of course, those games that will draw out our powers of observation and encourage us to take note of the things that we see during our walk are the best.

Counting the dogs

One such game is that of counting dogs. One player takes one side of the road and all the streets leading out of it, and the other player takes the other side of the road and all the turnings out of it. Then, as they walk along, they watch their own particular side and see how many dogs they can count. Every ordinary dog counts one point, but a black dog counts two, and for every perfectly white dog seen one point is deducted. Any player who sees a Dalmatian or coach dog wins—the game, no matter how many points others have made.

This game can, of course, be developed, and general objects taken instead of dogs. Thus, a perambulator, a truck, a two-wheeled cart, a policeman, a bicycle could score one point; a soldier, a sailor, a tricycle, or a four-wheeled van could score two; and for a rider on horseback, a motor-cycle, or a flock of pigeons, a mark could be deducted, and so on. Players can always make their own rules before setting out, the rules varying, of course, according to the district where the walk is to be taken.

On country roads sheep and cattle would be very common, and in city streets vans, carts, and automobiles would appear in great numbers. Of course, more than two players can play these games. If there are four or five players, sides can be formed.

Guessing the color of tails

Another good, quiet game that can be played while out walking is that of guessing the color of horses' tails. Every horse that we see coming towards us gives an opportunity for guessing. We must guess while the horse is some distance away, and the one who is proved to be right when the horse comes near scores a point.

A game for the city or town is to look out for the names of tradesmen, printed up over their shop-fronts, that form ordinary words. Names that are trades, for instance, might be selected, and one looks at one side and the other at the other side of the street. Every name over a shop that is the name of a trade would mean one point. Such words as Baker, Butcher, Brewer, Taylor, and so on, would score. Of course, other kinds of words could be selected—names of animals, like Bull and Lamb.

Another game for a walk in a shopping thoroughfare is to select some number, like 6, and every time it occurs over a shop-front, on a cart, or on any other similarly conspicuous place, for the players to say six. This would happen whenever such numbers as 6, 16, 26, and so on, appeared. But if the number appears twice running, as in 66, 166, and 266, the players must say six, six. In the numbers 61 to 69 the players must say six one, six two, and so on. Any failure on a player's part to keep to these rules means one mark against him, and the player wins who has the fewest such marks to his credit.

THE GAME OF ADJECTIVES

Of course, many games that are played in the living-room can be played equally well when out walking. There is, for instance, the old game of adjectives. Somebody starts by saying, "My mother had a cat." Then the players take it in turn to put an adjective before cat. First of all, it must be a word beginning with A, as an artful cat, an awkward cat, an apt cat, and so on. When at last a player cannot think of a word beginning with A that has not already been used, he has a point scored against him. If nobody can think of a fresh word beginning with A, then B is taken—a bad cat, a blessed cat, a beautiful cat, and so on. The one who has fewest points scored against him for failure to think of an adjective wins the game. This is a good game to play when a considerable number of companions are out walking together in the country.

THE GAME OF WHERE IS IT

One boy gives a description of an interesting place visited, a scene in history, or reads one of the descriptions given below, and the game is to guess the place or incident described.

THE CITY OF CROWDED STREETS

How hot it is! The sun's rays beat down from a cloudless sky so fiercely that our eyes turn with relief to the broad river speeding by eastwards. Low down on the banks are crowds of people with brown skins, and here and there some wearing white turbans. They are bathing in the water and crowding up and down stone steps, leading to curious little buildings. Can these be little temples? Farther along the banks steamers are busy loading indigo and saltpeter to take away. All around we hear strange speech, and we look in vain for clean streets. How narrow and crooked they appear!

Answer: Benares, India.

THE CITY WITH THE GOLDEN DOME

It is winter, and we are in a big city where the streets are deeply covered with snow; there is no sound of vehicles, only the tinkling of sleigh-bells and voices to break the silence. The shops have signboards and objects hung outside to tell what they sell, because many of the people cannot read, and certainly we cannot recognize the letters. We follow the way the sleighs take and come to a cathedral with a golden dome and wide granite pillars at the entrance. In front is a river—but a river frozen over. The ice will bear carriages; it will stay there till the spring, and when it melts there will be a religious ceremony and a blessing of the waters.

Answer: St. Petersburg.

TREES FOR EUROPE'S SHIPS

We are in a country covered with thick forest, so dense that it is only with great difficulty we can make a way through it. Hark! That must be men sawing wood and chopping down trees, and a young man, wearing a white helmet, is directing them, and —why, yes; those big animals working so hard are elephants. They are piling up the big logs with their strong trunks as though they were handling little sticks, and others are dragging along the chained trunks. The man tells us they are clearing a way for a railway through the forest, and the teak-trees they are cutting down are to be used for building ships. He says there are nearly twenty thousand square miles of tropical forest, and that some tigers and leopards have been seen near. Do you know what country we are in?

Answer: Upper Burma.

WHERE THE COCOA-NUTS GROW

We seem to be on an island in the midst of a big sea, for there is water everywhere, except here and there where small islands are scattered about. We are standing on a beautiful white sandy shore, dotted with lovely colored shells. It is only one o'clock in the day, yet, when we look at our little pocket compass and then at the sun in the sky, we find the sun is to the north of us.

Away inland the ground rises in terraces, forming a kind of amphitheater, up to the highest point in the middle of the island, which looks about 8000 feet above the sea, and reminds us of a broken-down volcano. We turn up one of the gorges, and see palm-trees with cocoa-nuts growing on them, great tree-ferns, sugar-canes, and oranges. We meet some contented-looking, brown-skinned natives, who tell us in broken French that they are going to dive for oysters to get mother-of-pearl from the shells that they find.

Answer: Tahiti, Society Islands, Pacific Ocean.

WHAT SCENE IN HISTORY?

We are in a tent in a meadow by the bank of a river. In the tent are gathered a number of men armed after the fashion of the Middle Ages, and through the opening of the tent we see troops standing. The men in the tent look angry and determined, and bend threatening looks on one who is the center of attention, and wears a crown. The foremost man of the group is urging him to put his signature to a document spread out on a table before him. At last he consents, sets his seal on a lump of wax and throws himself on the ground in a rage. Who is he, and what is the deed he has been forced to do by others and now so regrets?

Answer: King John signing Magna Charta.

THE LANDING OF A BRAVE BAND

We are on the coast of a wild, uncultivated country. Behind the bare rock on which we stand, forest stretches far inland. Off the shore is a small bark at anchor, and from it we watch men, women and children landing. They are dressed in plain garments, and seem to belong to the artisan class. They are evidently weary, yet how brave they must be to cross that wild sea in their small boat of 180 tons, and land with their little children on an unknown shore. Who are they and why have they come here, where there is neither shelter nor food for them?

Answer: Landing of the Pilgrim Fathers with their wives and children from the *Mayflower*.

AN INTERRUPTED GAME OF BOWLS

We have before us a bowling green, where men are intent on their play. Near by stands a man gazing out to sea across the harbor. He pays no attention to the game, but stands shading his eyes from the sun. Suddenly he sees something, for he turns, and striding up to one of the players, eagerly points out to him the beacon being lighted close by. But to his surprise the player goes on with his game of bowls, coolly remarking: "There is plenty of time to finish the game and beat the Spaniards too." Yet, all around, people are gazing out across the harbor, or making hurried preparations. What incident is this?

Answer: Sir Francis Drake warned of the approach of the Spanish Armada while at bowls.

A WARRIOR OF THE VANISHIING RACE OF RED MEN

THINGS FOR BOYS TO DO

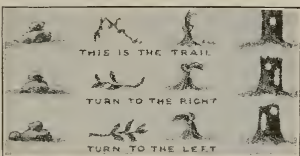
I am going east — I have not gone far — I have gone far — Gone five days' journey

TELLING A STORY WITH BRANCHES AND TWIGS

THE SILENT MESSAGES OF THE RED MAN

ALL readers of Fenimore Cooper's Indian stories know how clever the red men were at following a trail and reading the silent messages which their friends had left for them, and which would pass unnoticed by most of us.

This was, of course, in the last century, before civilization had spread into the far west, but even now he is very clever at giving and receiving silent messages, and some of the signs which he uses are well worth knowing. They will be particularly useful to Boy Scouts and all who love to spend their spare time in the open country.



Stones, twigs, grass, and tree signs

The red man can make use of any common object of the countryside to convey his message. If he wants to tell his friend who follows an hour or a day later which way he has gone, the road is marked by a series of stones every here and there, one being placed on another. Or, if there are no stones, a twig from a bush or tree is stuck in the ground at intervals, or a bunch of grass is knotted as shown in the picture, or a mark made on a tree-trunk. If the friend following is to turn to the right or left, the direction is indicated by a third stone or by the direction in which a twig is laid or the knotted grass is twisted.

Sometimes a more permanent and substantial sign is fixed up. A stick or small branch of a tree is stuck in the ground slanting-wise, and according as its free end points north or south, east or west, so an observer could know which way the traveler had gone. If the one fixing up the sign wished to indicate how far he was going, he would place another smaller stick upright in the ground against the slanting stick. If it was near the fixed end it meant he had not gone far, but if it was near the free end of the slanting branch the traveler had gone far. By placing a number of uprights along the slanting stick, the red man would show how many days' journey he had gone. Two sticks crossed means "this path is not to be followed." A circle drawn on the ground, with a stone or another small circle inside, means, "I have gone home." An arrow drawn in the dust of a road shows the route to follow.

But not only does the Indian use such methods of leaving information behind. He has a vast code of signs

The camp is here — I am lost — Good news — Summons to meet

TALKING TO DISTANT FRIENDS BY SMOKE SIGNALS by which he can talk to one of his own or a friendly tribe without speaking an audible word. Night is indicated by closing the eyes and inclining the head as though it were on a pillow. Day is shown by joining the thumb and forefinger, describing a circle with them, and pointing from east to west. Hunger is shown by sawing across the breast with the hand; scratching the chest means fire; the earth is indicated by pointing to the ground; to speak of a house or tent, the red man places his two hands together to form the shape of a gable roof; when he wants his friend to look at something he points to his eye and then at the distant object. "I understand" is shown by making a circle with the thumb and forefinger, and passing it away from the mouth. Wherever possible an action was indicated by imitating the operation, as in drinking, eating, burying something, and so on. The smoke of fires was formerly much used for sending messages to friends a long distance away in a level country like the prairie. One or more fires were lighted, and the rising columns of smoke conveyed the message according to an arranged code. Thus one column of smoke would simply indicate the position of the camp, two fires with two rising columns of smoke would be a cry of distress, meaning "I am lost," three columns means "I have good news to tell," four would be a summons to a council of chiefs, and so on. It is not necessary, of course, to copy the actual signs used by the Indians. We can take their idea, and adapt the signs to the particular country in which we happen to be.

Measuring distance by sound

Most boys and girls have a watch nowadays, and it is a very interesting occupation for the country to measure distances by means of sound. Sound travels at the rate of about 1142 feet in a second, which is equal to about a mile in four and a half seconds, or thirteen miles a minute. If, then, we have a watch with a second hand, and we can see the cause of a sound, we can measure how far it is from where we are standing to the place where the sound first arose.

If we are near a place where artillery practice firing their guns, we shall be able to measure the distance of the guns from where we happen to be by noticing the puff of the smoke, which indicates that the gun has been fired, and then watching the second hand of our watch and seeing how many seconds pass before we hear the report of the guns.

In this way we may also measure the distance of a thunder-cloud. We see the flash of lightning, and by means of our watch are able to tell how many seconds pass between the flash and the thunder-clap, which is, of course, the report of the flash or electric spark. Having this time and knowing the rate at which the sound travels, a very simple sum in arithmetic will give us the distance away of the thunder-cloud. Many other sounds will enable us to measure distances in the same way.

If we are on a broad river in a row boat on a dark night, we can, by striking the water with the flat of the oar and listening for the echo from the bank, judge roughly of our distance from shore. We can also tell which bank we are nearer to, for the nearest bank will send back the echo first.

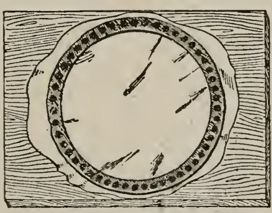
An easy way to make a telephone

To make a real telephone is a somewhat difficult task, but we can make a good telephone which will enable us to speak, in favorable conditions, up to a quarter of a mile away with very simple materials.

The materials we shall require include two boards about 14 inches long, 10 inches wide, and about half an inch thick. We should be able to get such boards by breaking up an empty box, and sawing up two of the boards to these sizes. Then we cut a circular hole about eight inches across in the middle of each board. We have first to mark the holes to be cut out.

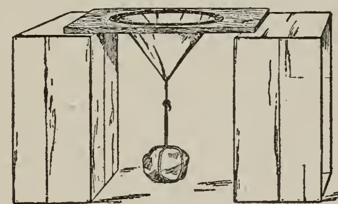
This is easily done by getting a plate about eight inches across, laying it face downwards in the middle of the board, and marking the wood round the edge of the plate with a lead-pencil. To cut out the holes properly we should have a keyhole saw or a fret-saw; but if we do not have either of these tools we can make shift by making holes with a gimlet right round the circle we have made. The holes should be as close together as we can get them. Then by using our chisel we can cut out the circular hole. Having done this, the boards are ready, and we can put them aside until we have the other parts of our telephone ready.

2. Button and wire



1. Fixing the bladder

Now we want two fresh beef-bladders. We blow them up hard, tie the necks with string, and put them aside for a few days to stretch. We must not leave them so long that they get dry. When they have stretched, we cut off the necks and soak the bladders in warm water until they are white and pliable. Then we put them over the holes in the boards we have prepared, putting the outside of the bladders to the wood. They should be put on evenly without



3. Stretching the bladder

creases, and not stretched in one direction more than in another direction.

Now we take a thin leather band, or some pieces of leather which we can make into a thin leather band, and tack it all round one of the holes above the bladder as seen in picture 1. This will attach the bladder securely to the board. The tacks should have big heads, and should be driven well home. Old boot-tongues will do nicely for the leather. We cut these up into strips about half an inch wide for the purpose. We fix the two bladders in this way to the two boards in which we have cut the holes. Then the edges of the bladder outside the leather strips should be cut away.

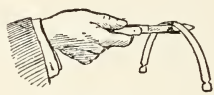
Now take a button and attach a thin wire to it by passing the wire through two of the holes in the button, as seen in picture 2, twisting it so that it will not come out. Make a hole right in the middle of the bladder and put this wire through. Then hang something heavy—a weight of about 7 pounds, or a large stone—to the other end of the wire, as seen in picture 3, putting the board in some position so that the weight can pull down the bladder. We treat both bladders in this way, and leave them in the sun until the bladders are dry and hard.

All that remains to be done now is to fix up the two boards and bladders at a distance apart, and connect them by fixing a wire to the two wires attached to the buttons. This wire should be fine copper or tinned iron wire. The wires may need to be supported if the distance is great. This can be done by hanging loops of string to the branches of trees, or to any posts that may be in the way. Then we may speak from either end, and the words should be heard distinctly at the other end. We should speak close to the bladder. When we wish to "ring up" the other end, we tap the bladder at our end with a pencil.

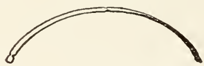
SIMPLE KITES AND HOW TO MAKE THEM

There are many different kinds of kites. Some are very simple, and these we shall see how to make in this article.

The ordinary kite is made with very simple materials, and its manufacture costs very little indeed. First, we require the half of a hoop. The size of the hoop depends upon the size of kite we are going to make, or, rather, the size of kite that we shall have will depend upon the size of hoop that we use. A hoop from a butter-cask will do very well for a small kite, and any grocer will be glad to give us one if we ask him. We do not use the whole hoop, but only a piece a little smaller than half of it. We choose the best for this purpose, and cut away the remainder. Then we thin the half-hoop with a pocket-knife, taking care not to take off enough to weaken it much. We must thin it equally all round, and we should test it to see that we have not made it lighter at one side than at another. The way to test it is simple. Take a piece of string and put it round the outside of the half-hoop, then cut it off to the exact length of the half-hoop. Double the string then, and again put it round the half-hoop as far as it will go from one end. Make a notch with the penknife where the end of the doubled string comes. Then balance the half-hoop on the edge of the knife-blade at this point, as seen in picture 1. If the half-hoop hangs



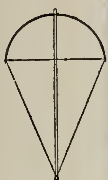
1. Testing the top

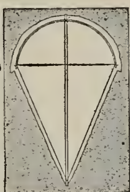


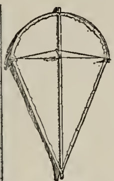
2. Top with notches

evenly, and does not hang down at one end more than at the other, it is all right; but, if one end hangs down more than the other, we must shave a little more wood from the heavier end, so as to make it the same weight as the other end. When we have got the half-hoop thinned properly and balanced, we make a notch at each side of each end, close to the end, as seen in picture 2, and put it aside till the backbone of the kite is ready. We require for the backbone a length of wood that will be strong and light. A piece of thin cane will do nicely if it is rather stiff.

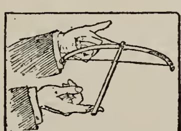
But a long slip of wood—say, from 24 to 30 inches long—will do about as well. We thin and smooth this slip, and then tie it to the notch in the center of the half-hoop, so as to leave 1 inch sticking up beyond the top of the half-hoop. Picture 3 shows the kite at a later stage, but shows also the position of the hoop and the backbone. Now tie a thin, strong string to one end of the half-hoop, or top, as we shall now call it, at one of the end notches, pass the string once round the backbone, and the other end tie to the notch in the opposite end of the top.


3. Frame of kite


4. Cutting the paper


5. Strut in position

Balance the whole by placing one end of the backbone on one forefinger, and the other end of the backbone on the forefinger of the other hand. We can then see if the top swings heavier at one side than at the other. If one side is heavier, we move the backbone along the string a little bit, until we find from the swing that it is right in the middle between the two ends of the top. Picture 6 shows how we test the balance.


6. Testing the balance

Having done this, we join each end of the top with string to the bottom end of the backbone, where we put a notch or a hole to receive the string. The kite now looks like picture 3. All the strings should be fairly tight.

We now get a large sheet of thin strong paper. A sheet of a large newspaper would do, but imitation parchment paper, if we can get it, is stronger and better. The paper must be large enough to cover the entire kite from top to bottom and from side to side. If the only paper we can get is in too small sheets, we can make one sheet large enough by pasting two or more pieces together at their edges.

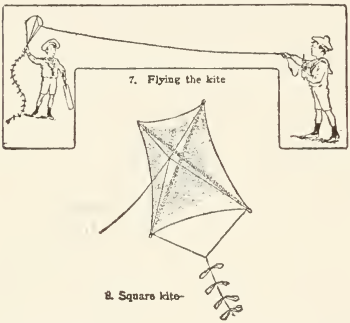
We place the kite on the top of the paper, on a table or on the floor, and, with a pencil, draw a line round the kite, about one inch outside the hoop top, and ½-inch outside the string sides, as seen in picture 4. Paste or gum the edges of the paper, and fold it over, and stick it down. Turn it over carefully, and stick on two or three patches on the back, thereby sticking the backbone to the covering paper and strengthening it. The kite is made, and we may prepare to fly it.

Tie a string at the back from side to side, from one end of the top to the other end of the top. Take a piece of wood about 4 inches long, and, having cut a notch in each end of it, fit it between this string and the backbone with one end on each. From the back, the kite will now look like picture 5.

Tie a string from top to bottom of the backbone in front. This is the bridle. It must be slack, so that the kite will fly properly.

Tie another piece of string to the lower end of the backbone and let it hang loose—say, about 5 yards long. This is the tail. Make some loops in the tail right down, 2 feet apart, and put in tufts of paper, and then pull the loops tight. These tufts are streamers, and make the kite look well when we fly it.

The kite is now ready for the field. We take it out when the wind is fairly strong. We should have a ball of string, or more than one ball, wound upon a stick. Tie the end of this string to the bridle so that the kite hangs horizontal when suspended, and tie a piece of turf to the end tail. One boy takes the kite by the bottom end, leaving the tail lying free. Another boy takes the ball of string to which the kite is tied, and goes away about 10 yards in the direction from which the wind is blowing. Both stand and wait for a breeze. Then, as the boy with the kite cries "Go!" he throws the kite violently forward into the air, and his friend runs his best. Then, if it has all been properly done, the kite soars aloft steadily in the wind, and



7. Flying the kite

8. Square kite

the string can be let out carefully and gradually. If the kite does not rise, the tail may be too heavy, and some of the turf must be taken off. If it wobbles, or rushes from side to side, the tail may be too light, and a heavier piece of turf must be put on.

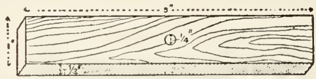
That is, perhaps, the simplest form of kite. A square kite is another very

2. Cutting one of the wings

simple shape, and is shown in picture 8. From this picture, and from the description of how to make the kite we have seen, we can make a square kite without further instructions.

A SIMPLE FLYING MACHINE

Most of us know that the propeller of a steamship, as it revolves, drives the ship through the water. This is because the slope of the blades drives the water away from the ship behind, and this pushes the ship forward. A very simple flying machine can be made on the same principle, and when we have made it we shall perhaps understand better how it is that a ship is driven



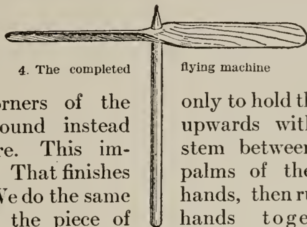
1. Wood for the flying machine

forward by the revolution of its propellers.

First, we get a piece of wood about 5 inches long, 1 inch wide, and half an inch thick, as illustrated in picture 1. Soft wood, such as is used for firewood, will do well enough, so that we may simply take a piece of firewood if we can find a piece large enough each way. Right in the middle of it and on the flat side we bore a hole about a quarter of an inch in diameter. We can do this with a gimlet, and we must do it carefully and slowly so that we do not split the wood. The hole is made right through from side to side of the wood. Picture 1 indicates the position and size of the hole. A little distance from this hole at one side we cut away the corner until we get it down to look like picture 2. The end of the piece that we have cut will be almost triangular in shape.

3. The wings after cutting

Now we begin at the opposite corner at the same end of the wood, and cut it away also until we have one end of the wood almost up to the hole in the form of a slanting blade, but very thin. Its resemblance to the blade of a ship's propeller begins to be seen, and it will look something like the right end of picture 3. We make the corners of the part we have cut round instead of leaving them square. This improves the appearance. That finishes one end of the blade. We do the same with the other end of the piece of wood, except that we cut away, not the same corners as we have cut away in the first end, but the opposite corners. Then we shall have the two ends cut away to the form of thin blades, but the slope of the one will be opposite from that of the other, as shown in picture 3. Our toy is almost complete.



4. The completed flying machine

We have now to fix a stem firmly into the center hole. A butcher's meat skewer, if made of wood, will do for the stem, or a wooden penholder, or even a thin lead pencil. The stem may be any length from 6 to 9 inches. We may glue the stem into the hole, but it is not really necessary. It will be sufficient if we push it in firmly, but not so far as to split the blades. When we have the stem fixed, we have only to hold the toy upwards with the stem between the palms of the two hands, then rub the hands together quickly, and release the machine as we make it spin. It should soar aloft as high as the roof of a house if we have done it properly. If we have not done it properly, we may find that the toy strikes the ground at once instead of flying. If so we may know that we have spun it in the wrong direction before releasing it, and we can do better at the next attempt. A little practice will enable us to make it soar high every time.

5. Flying the machine

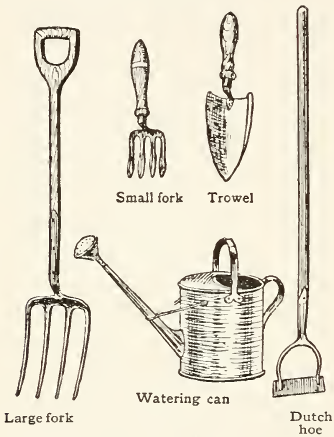
THE PLEASURE OF A LITTLE GARDEN

THE spring is a capital time in which to start a little garden of our own—the earlier the better, but the middle of April will do if we have not thought of it before.

Gardening is a splendid hobby, because it gives us plenty to do and plenty to think about, and plenty of wonderfully interesting things to find out. When we make a garden and plant it, we set ourselves the task—and it is a very pleasant one—of looking after the welfare and health and comfort of all sorts of plants, many of which have different tastes and requirements; and it is one of the experiments we must always be making to see if we are giving each plant just what it most wants. Some like a great deal of sunshine, some like the shady places; some like a dry position, some a moist one; some like to grow among the stones, some stretch up, and need arches or posts to support them.

After we have acquired our plot of ground, we need a supply of tools before we can transform it into a beautiful garden; and we ought to get tools as large as we can comfortably handle. This applies especially to such an important tool as the spade. Other tools that will be needed will be a hoe; and many people find what is called a "Dutch" hoe the most convenient to use for weeding.

A rake will be necessary to smooth the surface and to clear up the rubbish. Something smaller than the spade will be needed for planting, and for this purpose a trowel is useful; but where it is a question of digging holes in ground where many bulbs may lie hidden, a trowel may damage them, so that a little four-pronged fork in a handle of the same length as that of the trowel is very useful; and, if we cannot have both, the little fork will do all that the trowel does, and should be the one we should choose.



THE LITTLE GARDENER'S TOOLS

A large fork set in a handle the same length as the spade is a most useful tool, and can often be used for digging, especially round about plants already established, as it is not so likely to injure their roots as the spade. A watering-can is necessary, and one the rose of which takes off and on should be bought, as quite as often we need to water through the spout as to sprinkle the water through the rose. A wheelbarrow is useful to have, either to bring soil or to cart away weeds, leaves, and other rubbish; or, failing that, a strong basket will take its place.

The first work in the garden plot will be to dig it as deeply as you possibly can—that is one of the reasons why it is necessary to have a spade that really can do some good work, because deep digging is of the utmost importance. You can understand that the deeper you work the soil the better it is for the roots of your plants, and in well-worked soil these go creeping out in all directions to find food and drink wherewith to build up and sustain healthy and sturdy leaves and stems and flowers.

The middle of April is not too late to sow seeds of many plants that will flower during the summer and autumn. Plants that flower so quickly as this are called annuals. They do not come up year after year in the garden, as some plants do, and live for many seasons. No; annuals are the shortest lived of all plants, and you must sow seeds afresh each year. But an annual accomplishes a great deal in its little life. You sow the seed; the seedling appears, grows quickly into a little plant; the buds appear, and open out into beautiful flowers. Then they fade, and the seed-vessels grow; and when the seed has fully ripened the plant dies. And all within the year!

Among the prettiest and brightest of annuals are larkspurs, poppies and nasturtiums. The sweetest smelling is, perhaps, the mignonette, and one that is interesting for its quaint seed-vessels is known as love-in-a-mist.

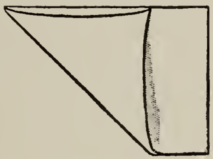
The great point to remember in seed sowing is to sow as thinly as possible, and however thinly we sow we shall have to draw out many of the seedling plants when they appear, but we can think about that later on; though any boy or girl who already has a garden, and has reared his seedlings, may at once set about thinning them, as it cannot well be done too soon.

Some of the seeds may be sown in lines, especially where we need a row to serve as an edging; or, again, they may be sown in circles. These, when they grow up, make nice patches. There are a few rules always to be borne in mind when sowing seeds in the open ground. The soil must not be so wet that it is sticky and hangs together in lumps, neither should it be so dry that it is like powder. Second, the seed must not be buried too deeply; and third, it must be sown thinly.

If the soil is too wet, it is better to wait for a few days until wind and sun have partially dried it, and if it is too dry it must be watered.

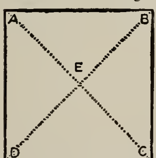
HOW TO MAKE A PAPER BOX

Any clever boy or girl can make a neat paper box suitable for bonbons, valentines or party favors. First, take a piece of paper, which should not be too thin or too soft. A piece the size of this page or a little smaller will do nicely. Now make the paper exactly square. You can do so easily by folding it over as shown here.



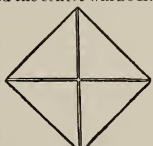
Cut off the part where the folded upper piece does not cover the lower piece, and what remains will be exactly square.

You have already folded the paper diagonally—that is, from corner to corner. Make a good crease by pressing it with the fingers at the fold, then open it out and hold it diagonally from the other corners, and press the fold well down with the fingers. The paper will now be square and creased as in this picture.

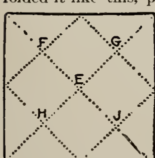


Notice the letters on the picture, so that you can understand easily what to do. So that we may understand what follows more easily, we shall call the four corners A, B, C, and D, and the center will be E.

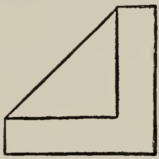
Now fold all the corners in carefully so as to touch the center, and make the paper as here shown.



The paper will now be in the form of a square, but a much smaller square than formerly. Having folded it like this, press it down well at the folds so as to crease it plainly.

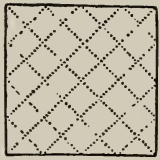


You will now have four more creases, and when you open out the paper again it will be creased where the dotted lines are in the next illustration. The other letters—F, G, H, J—mark where the creases cross. Fold the corner A over to the spot J, as seen in this illustration.



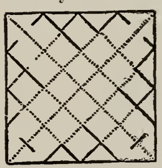
That will make another crease. Now make another crease by folding the corner B over to H; another by folding the corner C over to F; and another by folding the corner D over to G.

We still want four more creases. Make them by folding A over to F, B over to G, C over to J, and D over to H. The paper is now creased as shown here.



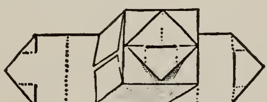
Every one of these creases is necessary to make the final box, although, as the paper is now, it is not easy to see why all these marks are wanted. But we shall see presently the use of all the creases.

Now you must use scissors. Cut along where there are black lines instead of dotted lines in the next picture.



You now have a paper which does not look very like a box. But you have only to fold it up in the proper way, and you will see that it is. Fold over the corner at D like this:

and slip it into the slit near B. Now fold in the flap at the side, and you have it like this:



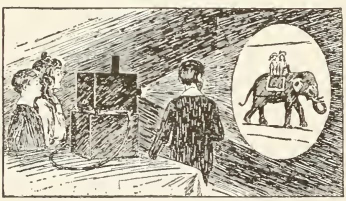
Fold over the corner at C, and slip it into the slit at A, and the box is now finished. If you have made it properly, it will be very neat and perfectly regular.

A MAGIC LANTERN FOR PICTURE POSTCARDS

FOR winter evenings nothing is more interesting than a good magic lantern. Unfortunately, the lanterns that are bought at the shops have this disadvantage: they will show only slides that have been painted or photographed on glass, and these slides cost money; and even if the owner of the magic lantern has a good many of them, he soon gets tired of showing the same pictures over and over again.

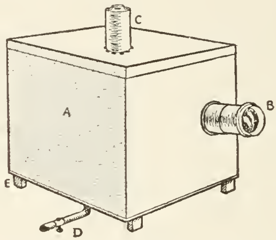
Most boys have wished they could have a lantern that would show any sort of picture on the screen, and so we are going to tell them how they can easily make one for themselves.

The magic lantern here described can be made out of an old biscuit-tin. It does not require glass slides, but it will throw on the white sheet in natural colors a big picture of anything that is put into it. When we have made it we can put picture postcards into it, or funny drawings that we can cut out of magazines, and it will throw them on the screen just as well as an ordinary magic lantern with glass slides.



1. Magic lantern showing picture postcards

Picture 1 shows the lantern being used; the picture of an elephant in the lantern is being thrown upon the screen in front.



2. This is the lantern complete. A is the body of the lantern; B is the sliding lens; C is the chimney; D is the gas bracket; E marks the feet on which the lantern stands.

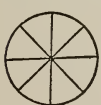
We can see the advantage of this at once. Probably we have hundreds of picture postcards or photographs that would look splendid if they were thrown on the screen. Well, we can use all these, and never get tired of this sort of magic lantern, because we shall always be getting new pictures for it of one kind or another.

Get a large square biscuit-box. Possibly we can find one in the house; if not, any grocer will sell one. This box will form the body of the magic lantern, as seen in picture 2.

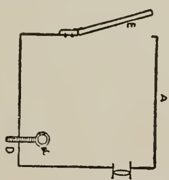
Now we must fix into it a lamp or a gasjet that will give a bright light. Of course, the brighter the light, the brighter the pictures will be on the screen. An incandescent gas-mantle gives the best possible light, and one of these can really be fixed more easily than a lamp. We can buy an incandescent gas-burner complete, and any gas-fitter will supply a short bracket of the kind shown in the illustration. We have then only to make a small hole in the bottom of the biscuit-box, put the burner inside and the bracket underneath, and then screw them together. When this has been done, the burner will be fixed in the required position quite firmly.

It will be necessary now to make four feet for the lantern to stand upon, as the gas-bracket at the bottom makes it uneven. Little cubes of wood, about two inches high, will form the feet. If we can find any wooden "bricks" in an old toy-box, these will do splendidly. We have only to place one at each corner of the box, to drive nails through the tin from the inside, and the feet will be firmly fixed in a few minutes.

5. Chimney made from coffee-tin



3. Opening for the lens



4. Diagram of the lantern looking from above

Now we must get a lens for our lantern. These are sold at the shops where magic lanterns and cameras are kept. We had better explain exactly what we want the lens for, and the man will understand. The lens should be mounted in a brass tube that slides backwards and forwards in another tube, so that we can focus the picture on the screen.

Now we must cut a hole in our biscuit-box, and fit the lens in the position shown in the illustration. This is quite easy, if we get from a tool-shop a small tin-cutter. With one of these we can cut the tin in a few minutes, and it will also be useful later on. The tin-cutters are merely strong scissors.

When the hole is cut, fit the lens into it. If the lens has a "flange," that is to say, a flat rim, with holes for screws, this will be very easy. All we have to do is to bore holes through the tin, and then fix the lens with strong brass "paper fasteners." If it has no flange, the simplest way is to cut eight slits, all meeting in a point, as shown in figure 3. Then bend the pointed pieces of tin inwards, and they will form a support for the lens tube.

We now have the gas-bracket and the lens in position. The next thing to do is to make a door at the back of the lantern, so that we can put the pictures in. Cut an oblong hole, about the size of a postcard, not in the middle of the box, but on one side opposite the lens, as shown by diagram in picture 4. When we have done this make a wooden door with hinges, as shown in the picture.

The lantern is now complete except for the chimney. This can be made out of an old coffee-tin. Cut a hole in the lid of the box exactly over the gas-bracket. Then make five or six cuts round the top of the coffee-tin, each about one inch long, bend back the pieces of tin, and then you will be able to fix the chimney to the top of your lantern with brass paper fasteners. One glance at picture 5 will make all this clear. At the bottom of the coffee-tin, which is now the top, we must cut a hole about as big as a twenty-five cent piece, and fix over it a flat piece of tin with paper fasteners. This opening will allow the hot air to escape, but not the light. A few small holes must also be made in the back of the lantern, so that air may come in, otherwise the gas will not burn properly.

Now the whole lantern is complete, and if we have done everything neatly it will look quite nice. If we wish it to look particularly smart, we can give it a coat of Brunswick black. When we want to try our lantern, we fix a white sheet over one wall of the room. Then place the lantern on a table about eight or nine feet away, and connect the gas-burner by means of a rubber tube with the ordinary bracket on the wall. Put on the incandescent mantle, light the gas, and then put the lid on the lantern.

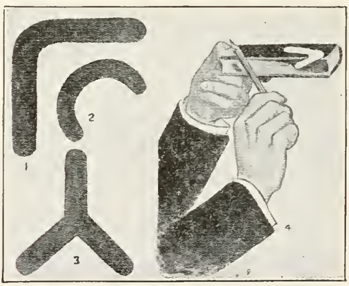
Now open the door at the back, and fix a picture postcard to the wood with drawing-pins, and the moment the door is closed a large picture of the postcard will be thrown on the white screen. We must slide the lens backwards or forwards until the picture on the screen is quite sharp, and then we can show just as many more postcards or other pictures as we please. By the way, whatever sort of pictures are placed on the door, remember to pin them on upside down. They will appear right way up on the screen.

HOW TO MAKE AND USE A BOOMERANG

Any boy or girl can make a boomerang of cardboard that when flung out into space will travel for a certain distance and then return again.

Boomerangs can be made of various shapes, but the simplest and most familiar is that shown in the first picture. We take an ordinary postcard of medium thickness, and first draw the boomerang carefully to the proportions shown in the picture, making it as large as the postcard will allow.

Then, having drawn it, we lay the card on a flat piece of wood resting on an even surface, and, with a sharp penknife, cut it out clearly and neatly. No jagged edges must be left or the boomerang will not work. We must not cut it out with scissors, for that causes the card to curl, and a cardboard boomerang must be perfectly flat.



Three kinds of boomerangs, and the way to throw them

Another very good shape for a boomerang is that shown in the second picture, and here again we first draw the outline on a postcard, and when we have got the curve and the proportions quite accurate, we cut the weapon out with a sharp penknife, proceeding in exactly the same way as before.

A more complicated form of boomerang is that shown in the third picture. Here we have three arms, and this must be made in the same manner as before. We must be particularly watchful that there are no jagged surfaces in the angles where the arms join one another.

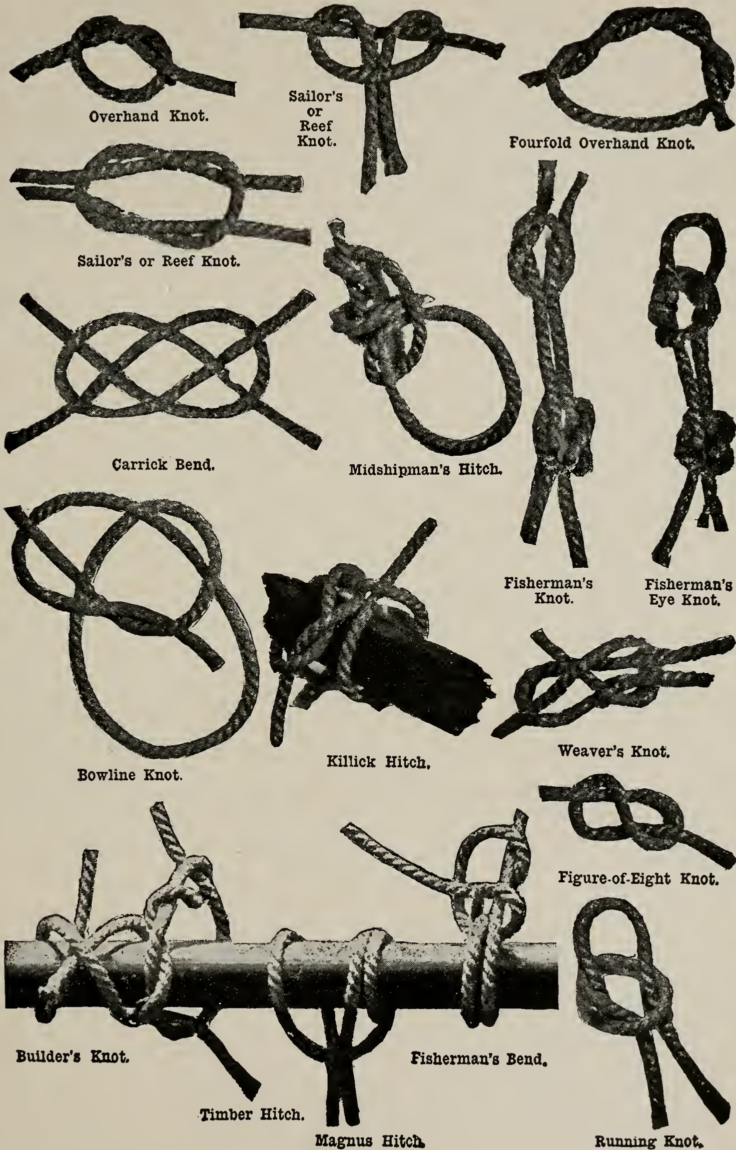
It will be noticed that in the case of all three shapes the ends are carefully rounded. This is important or the boomerang will not work properly. It may sail through the air swiftly and well, but it will not come back.

The method of throwing the boomerang is the same in all cases, and the picture on this page showing how the first shape is driven into space will explain how to act in each case. The boomerang is placed on some flat surface, such as a book, and then it is flicked off sharply with a pencil. As it sails off into space it will whirl round and round, and, after going some distance, will describe a curve and come swiftly sailing back home again.

Any failure of the boomerang to return to its thrower will be due to faulty shaping or cutting out, or to too heavy cardboard.

The reason for the curious flight of the boomerang is not, even now, properly understood by men of science, but it is known that, owing to its shape, the air resists one part more than another, which causes it to fly in a more or less circular path.

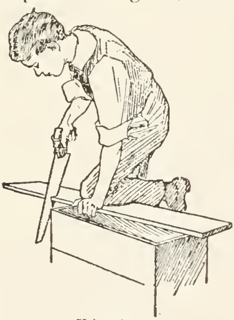
KNOTS IN GENERAL USE BY SAILORS AND BUILDERS



THE BOY'S CARPENTER SHOP

EVERY boy should have a box of tools and know how to use them. With practice many things useful and ornamental may be made. The most commonly used tools are not difficult to manipulate; and although written instructions may help, a little practice should soon overcome any difficulties, especially if the right methods of holding, setting, and using are followed. When the tools are mastered it is possible to begin real work. The tools most needed will be a claw hammer, saw, chisel, plane, screw-driver, foot-rule, set-square, gimlet and possibly a hatchet. These should be purchased of the best quality one can afford.

Wood has what is called a grain, which is always up the way the tree has grown, and it can be split the way of the grain, but not across. When you wish to cut wood across the grain you must use a saw. When the grain of the wood is very regular you can split it evenly, but if the grain is twisted you cannot do so. Therefore, even when you want to have the plank of wood cut the way of the grain it may be necessary to use the saw instead of the hatchet. There are many saws. The kind you want is a handsaw, say about fourteen or sixteen inches long. You can use this both for sawing the long way of the grain and across. You must work the saw backwards and forwards regularly, not rocking it from side to side, or you will cut unevenly; and not jerking it out and in, or you will blunt the saw, and tire yourself. Before beginning to saw, make a pencil line on the wood where you want to cut it, and make the saw follow the line very carefully.



Using the saw

A hammer is a tool you cannot possibly do without. Its chief use is for driving and pulling nails.

A chisel is used to cut the wood where a hatchet or a saw would not be suitable. We use a chisel, for instance, to cut away the wood to make room for a lock

Using the hatchet

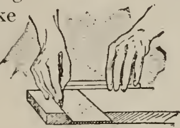
on a door, and sometimes before putting on hinges.

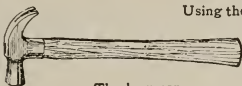
A gimlet is used to make holes chiefly when screws are to be put in. For ordinary driving nails it is not necessary to make holes with the gimlet unless the wood is very hard and liable to slit.

The screwdriver is for putting in screws. It is pressed against the head of the screw-nail with its point in the slot of the head, and is turned round at the same time.

If you look at an ordinary wooden fence and then at a door in a house you will notice a great difference in the surface of the wood. The fence will probably be rough, or almost hairy. The reason is that the door has been planed and the fence has not. All wood to which we want to give a smooth surface must be planed. Another reason for planing is that if we paint wood that has not been planed we use much more paint than we should use if the wood had been planed. In using the plane, push it forward on the wood steadily, and press upon it evenly all the time. The plane iron and the chisel must be kept sharp, and if you can afford to buy an oilstone you should do so. The stone is called an oil stone because it is used with a little oil in rubbing the edge of a tool upon it.


The square


Using the square


The hammer


The chisel


Using the hammer


Taking out nails

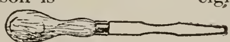

Using a chisel

The first thing you might make with your tools is a box in which to keep them. You can no doubt find somewhere an empty soap or sugar box, or you may probably buy one from the grocer for a few cents.

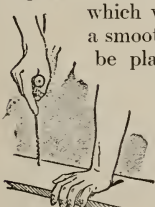
Having the box, take the sides apart by pulling out the nails. Now measure off two pieces eighteen inches long and six inches wide. These are for the two sides of the tool box. Then measure off two other pieces six inches by seven inches to make the ends. Cut out these pieces, plane them until they are smooth enough, and nail them together so


Straightening a bent nail


The gimlet


The Screwdriver


The plane


Using a gimlet

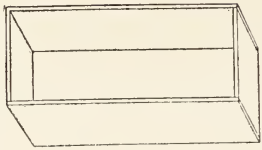

Using a screwdriver

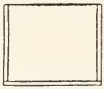

Using the plane

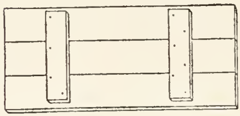
that they look like the top picture, with the end pieces fitted inside the sides.

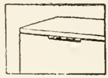
The total length when nailed up is eighteen inches, and the width will now be more than seven inches—it will be eight inches if the wood of the sides is half an inch thick. Now nail on pieces of wood to make the bottom, having cut them out as you did the sides.

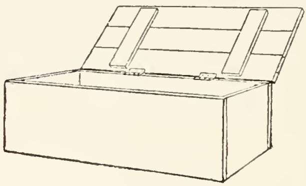
To make the lid, take one or more pieces of wood making the same width altogether as the bottom. Nail across them, as in the drawing, two pieces that do not go quite to the edge. The lid is now made. You can use it as a lift-off lid or you can put it on with hinges, which you can buy. Fix these on with screws, screwing them to the edge of the lid first. Then chisel away a little of the wood from the back of the box so as to make room for the hinges. You can put a lock on it if you like, and fit inside a tray to hold nails and other small things.


The ends and sides of the box


Box end, and position of bottom


The lid of the box


The position of a hinge


The completed tool-box

MAKING A SET OF BOOKSHELVES

IN PROCEEDING with our carpentry work, we must not go too rapidly. We shall do better work if we make very simple things at first. Another point to keep in mind is the utility of the articles we set ourselves to make. Here we shall see how to make an exceedingly useful article—a set of hanging bookshelves—which may be attached to the wall.

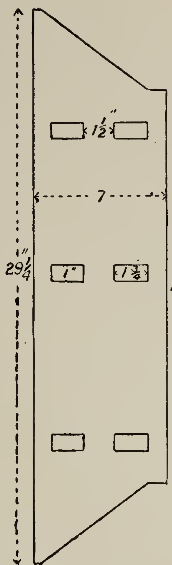
Everyone can use an article of this kind, and everyone with ordinary intelligence and the necessary tools can make one. The sizes given in the sketches are good useful ones, but the best sizes for the article to be made depend upon the space available for its accommodation. Thus everyone who makes the bookshelves from these sketches must first decide if these sizes are the best in his individual case, and if they are not he must modify the sizes given to suit his own case.

Kind of wood to use

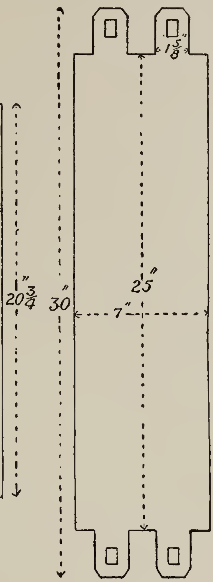
We have first to decide what kind of wood we shall use. We could use oak, beech or birch—perhaps oak looks better than the other two for the purpose—but all these are hard woods, and it will be much easier for us to use a soft wood, such as pine. Hard woods are much more difficult to work. We can use soft wood, and after the shelves are made we can stain them to imitate any of the harder and more expensive woods.

Size of shelves

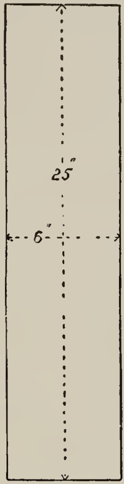
In picture 1 we show one side of our hanging bookshelves with all the sizes marked. We first cut out two pieces of the wood we are using—pine, for instance—to this shape. They must be fairly strong, and we should make them so that the finished thickness shall be not less than one inch, so we had better use wood 1⅛ inch thick and reduce it to one inch by planing it. The holes in the sides we can make with our chisel, and we must be particularly careful that each pair of holes is exactly in the same horizontal line, so that the shelves may be quite flat.



1. Plan of sides



2 Plan of shelves

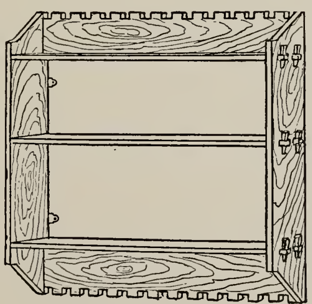


3. Plan of back piece

4. Dowel

We must also see that the two sides are exactly alike. Having cut the two pieces, we must finish them carefully with the plane so as to have them true and smooth, afterwards rubbing them well with sand-paper. Use No. 1 sand-paper first, rubbing the surface and edges carefully until they are as smooth as the sand-paper can make them, and then we use No. 0 sand-paper, which will give them the final touches. It is more important to have the sides smooth than it is to have the shelves smooth, because the former are more exposed to view.

We shall now make the three shelves alike, and thereby simplify matters. Picture 2 shows the shape and the sizes to which we should make them. The thickness of these pieces when finished should not be less than ¾ inch and preferably ⅞ inch, so that the wood, when we begin, should be at least 1 inch. Having made the shelves, we fit them into the sides so that the ends go through the holes we made. We shall then want twelve taper pins, or dowels, for the holes in the ends of the shelves to hold them in position. Now nail on two back pieces, as shown in picture three, and the shelves are complete, except the mirror plates, as shown in picture five.



5. The completed bookshelves

JOINTS AND MORTISES

The simplest forms of joints are not too difficult for the amateur to make, which is fortunate, since one cannot go far in wood work without using them.

THE DOVETAIL NAILING, or sloping the nails (Fig. 13A). This method is necessary only when the nails are driven into the end grain of the wood, as in fixing the sides of the box to the ends, in which case the fiber of the wood does not grip the nail. Figure 13B explains the hold which a nail has when it enters the wood at right angles to the grain.

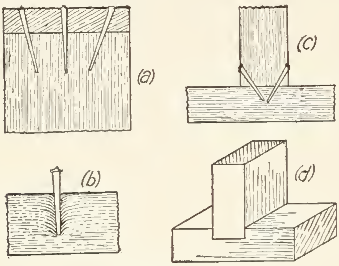


Fig. 13.—(a) Dovetail nailing; (b) nail forcing wood fibers apart; (c) skew nailing; (d) housing.

HOUSING (Fig. 13) is the name given to the joint when a groove of sufficient size is made in one piece of wood to admit the end of the other piece. Bookshelves are fixed in this way. Such joints may also be nailed through the ends but this should not be necessary if the shelf fits closely into the groove and there is a back to hold the piece of furniture rigid.

MORTISE AND TENON JOINTS are used in the making of doors, tables, and various kinds of woodwork. They are applied to the finest as well as to the heaviest kinds of construction, and vary in shape according to the work they have to do. The mortise is the hole, and the tenon is the piece driven into it, the word tenon meaning "that which holds." In house doors these tenons go right through the uprights, or "stiles," of the door, and are wedged on the outside edge (Fig. 15, *a*). This

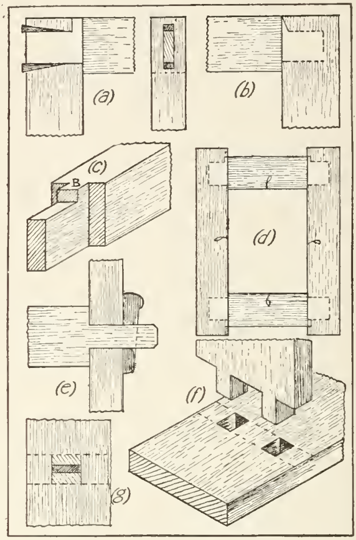


Fig. 15.—Mortise and Tenon Joints

"through" tenon is only necessary in large work, where extra strength is required. In this tenon the wedge should not be driven right in, the final position shown in Fig. 15, *a*, being about correct. When cutting mortises in stiles near the ends, always leave a waste piece on for strength in working, as in the case of the frame (Fig. 15, *d*). In Fig. 15, *b* is seen a "stopped" tenon, the joint generally adopted by cabinet-makers where any great strain or strength is not required, while the tenon itself is shown in Fig. 15, *c*, with a piece left on at B, which is called the "haunch." This haunch serves two purposes. It fills in the space made by the groove when the door is paneled as in an ordinary house door; and it gives rigidity and strength to a rail, as in the frame of a table. The tenon and haunch is shown in Fig. 15, *b*, as it would be in a table, the haunch in this case being sloped. A tenon should occupy, laterally, about one-third the thickness of the wood. In cutting down the tenon be careful to keep the saw *outside* the lines.

Fig. 15, *d*, is an illustration of a door frame suitable for a cabinet or cupboard. It is made with a stopped tenon, and shows the haunch, which would only be used if the panel is be to grooved in. The "face" marks all finish off on the outside edges—a rule that should always be followed—and it will be noted that the uprights or stiles are longer than the actual length of the door for the reason given above, and are left on until the door has been glued up and dried, and is ready to be fitted into its frame. A tenon will enter the mortise easier if the end corners are cut off, as a sharp square edge is likely to catch on the uneven sides of the mortise.

Fig. 15, *e*, shows a form of tenon which goes right through the wood and protrudes sufficiently to allow a wedge to be driven into a hole in the projecting part. This is generally used in heavy work and church furniture, but is also a great advantage in such a thing as a standing bookshelf, as it allows for easy separation of parts if occasion requires. It is not glued, for it is evident that the further in the wedge is driven the tighter does the joint become. At the same time there is the danger of forcing out the extension piece if the wedge is driven in too far.

The through tenon shown in Fig. 15, *f*, is used when divisions in bookcases, cabinets, and showcases, etc., are fixed into the tops and bottoms.

Both sides of the boards should be marked for the mortises, and the cutting out will be made easier if a hole is bored right through first; then cut halfway through with a chisel, and turn the board over to finish from the other side. On no account should the mortise be cut through from one side only, as there is a danger of breaking the wood away at the back. Neither should the tenons fit too tightly across the width for fear of splitting the board.

Mitre joints

The true mitre joint is made at an angle of 45°, as in picture-frames. In the first place, the mitre is sawed in a mitre box and the "return" or corresponding mitre should follow the preceding one, as 1, 1, and 2, 2, in Fig. 19, *a*, to ensure a correct intersection.

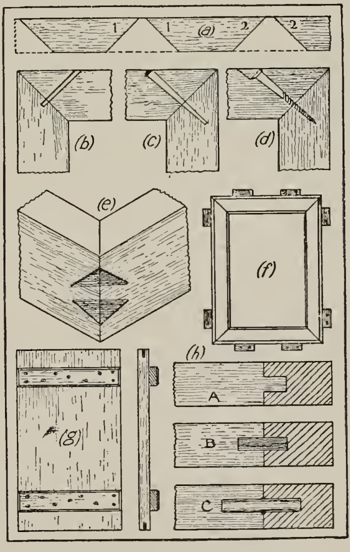


Fig. 19.—(a-f) Mitre joints; (g-h) clamping

It is a fatal mistake to cut the molding into lengths first.

If the angle is not a true one, the frame will not be square. It is quite possible to cut a true mitre at once with a fine saw. Frame-makers use a hand-machine for the joint, but an amateur is not likely to include this in his outfit. The makers also use a vice to hold the joints while they are being nailed, but the worker at home must rely on simpler methods.

Another way of keying mitres in thin work, such as a tray, is to build up the sides and ends of the tray on a square piece of wood with dimensions equal to the inside measurements of the tray-to-be. The pieces are held in position by pins or a little glue. If a piece of paper is put between the back pieces and the wood, and the three are glued together, they can be separated subsequently by inserting the blade of a thin knife between wood and wood. The slightest touch of glue is sufficient for the purpose.

STAINING AND POLISHING WOOD

WOODWORK is stained to improve its natural color. The difference between stain and paint is that stain sinks into the fibers of the wood, and dyes them, but leaves the grain of the wood showing as plainly as before. Paint forms an opaque coat on the surface which quite conceals the material beneath. Generally stain is used to make a cheap wood look like an expensive one. The colors used are chiefly imitations of walnut, mahogany, and rosewood. These stains are used on lighter colored common woods, such as pine, and only for good appearance and not to deceive people, for anyone with a little experience can tell what the wood really is.

Different colors in stains

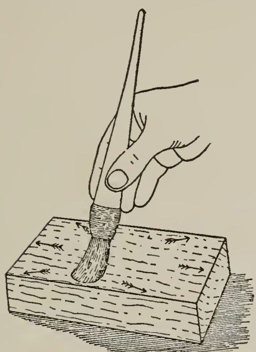
Sometimes, though not often, colors quite different from that of any wood, such as green, blue, or red, are used as stains. Very often fancy woods are darkened and improved in appearance by stains of the same color as themselves. Stain is used also to darken lighter parts of the wood to the same shade as the rest. Wood may be darkened in colors slightly by rubbing oil into it. Oak and mahogany can be darkened by ammonia. The usual way to do this is not to wet the wood with it, but to shut it up in a case or small room with saucers of liquid ammonia. The fumes of the ammonia darken the wood in a few hours. In all cases stained wood must be darker than the natural color, for a dark surface will show through a lighter stain.

Stains for wood are sold ready for use in small bottles. They may be put on with a brush, or rubbed in with a rag. The neater way is to use a brush. Generally two coats are given. The best result can be obtained by using weak stain and applying a number of coats, allowing each to dry before putting on the next. The surface must be smoothed with sand-paper before the first coat and after each coat has thoroughly dried. Otherwise it will feel and look rough, for anything which wets the wood causes its surface to roughen as it dries. Varnish stains are often used instead of simple stain. These are varnish and stain combined and are not so good.

Effect of varnish

Varnish does not conceal the character of the wood beneath it, for it is almost transparent unless something is added to color it. It simply produces, when dry, a hard, glossy film on the surface, which protects the wood from dampness and dirt. Quick-drying varnish consists of shellac dissolved in methylated spirit. The spirit evaporates and leaves a thin layer of shellac on the wood. Shellac varnish is used only for indoor work. In making varnish for work exposed to the weather it is necessary to use linseed oil instead of spirit, and copal, or mastic in place of shellac. Varnish may be used either on the bare wood or on paint.

Varnish is applied with a brush. Two or three coats are put on, each being allowed to dry and then smoothed with fine sand-paper before applying the next. For large surfaces a large brush should be used, so that



1. How to varnish wood

the varnish can be spread quickly. For small work a small brush is better. The varnish should be put on uniformly, so that some parts shall not be more thickly coated than others. Varnish should not be allowed to run over edges or corners of the article being varnished, and the brush should be used so that it does not leave marks of its own all over the work. The best way is to take one surface at a time and cover it with varnish as quickly as possible—that is, if ordinary shellac varnish, which dries quickly, is being used. The brush should be held as shown in picture 1, and should move in line with the grain of the wood. If it is used across the grain, marks of the brush will show more distinctly. To prevent varnish from getting squeezed out of the brush and running over the edges of the wood, the brush should always move outwards to the edges, as indicated by the arrows in picture 1. In approaching the ends of the wood it goes directly to the edges, but in passing along the sides its direction is only very slightly diagonal towards the edges there, so that the movement shall be as nearly as possible in line with the grain. Spirit varnish dries quickly, but to obtain the best results each coat should be allowed several hours to harden before sand-papering it down for the next. After the first coat, old sand-paper worn smooth should be used, and the work is not rubbed down at all after the final coat. Sand-paper should always be rubbed in line with the grain of the wood. If rubbed across, it scratches the surface too much.

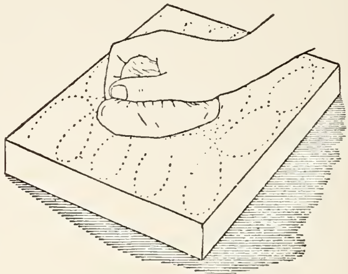
Polishing and varnishing

The difference between polishing and varnishing is chiefly in the method of application, for shellac varnish and polish are practically the same thing.

The distinction between varnishing and polishing is that varnishing is done with a brush, and polishing with a rag. Polishing requires more skill and time, but it gives a smoother and glossier surface than varnishing. It is important in polishing that the pores of the wood shall first be thoroughly filled, so that the polish cannot sink in and lose its luster. A number of applications of polish with long intervals for drying will do this, but it is quicker and cheaper to fill the pores with some other substance before beginning to polish. The filler is generally whiting or plaster of Paris dissolved in water, turpentine, or oil, and colored to match the wood. It is rubbed in and allowed to dry, and then the surface is sand-papered smoothly. The wood is now ready to receive the first application of polish.

The rag used in polishing is called a rubber. It should be a piece of soft white linen. This is used as an outer covering to a pad of cotton-wool.

The cotton wool is moistened with polish, and the single thickness of rag encloses it and is drawn up like a pudding-cloth at the top and grasped by the hand while it is used. The pressure on the rubber should not be heavy, and a few drops of linseed oil are put on the rag to make it move about freely without tendency to stick. The polish is put on the cotton-wool only, and gets squeezed through the rag in rubbing. The method of rubbing depends to some extent on the shape and size of the work. First, it is necessary to cover the surface of the wood with polish as quickly as possible. This is done by moving the rubber in large sweeps either with or across the grain or both. The direction is not important as long as the polish is rubbed uniformly all over the surface. On a large flat surface, as in picture 2, the rubber may be moved in curves or spirals, as shown by the dotted lines. These are only drawn as lines, but the broad surface of the rubber would, in following them, polish the entire area of the wood. For getting into the corners of panels and similar parts the rubber must be squeezed into a pointed form which will reach those parts. After the polish has been applied in this manner, the work must be laid aside for at least a day. Then a second application is given in the same way as the first.



2. Polishing a large surface

In the best work this process is repeated a third time or even a fourth, and long periods are allowed between each to allow the polish to sink in as much as it will. In sinking in, and hardening, it loses some of its gloss, and as long as this occurs the work can be improved by fresh applications of polish. This is called bodying in. The final process in polishing is called spiriting off. In spiriting off, the rubber is moistened with methylated spirit instead of polish, and is rubbed lightly over the surface to remove smears caused by the rubber in bodying in, and also to take up the oil, which, when present, gives the surface a dull, greasy appearance. The last movements of the rubber should follow the grain of the wood—that is, the rubber should move in straight lines with the grain.

THINGS A BOY CAN MAKE FOR A BAZAR

Here are other things that boys can make for a bazar:

Toasting-forks made of wire. The wire can be bought at any ironmonger's, and should not be too thick; it can be twisted double or treble to give sufficient stiffness to the handle.

A set of furniture for a doll's house—chairs and tables—made from firewood, the pieces being joined together with glue.

A boot-brush box with a hinged lid can be made from an old egg-box.

A flower-pot case made of wood and covered outside with cork bark, or enameled in some dainty color.

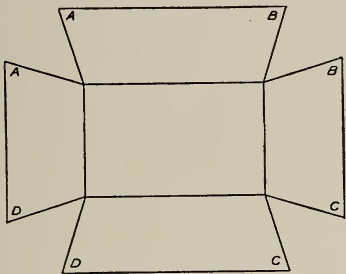
Picture-frames of different sizes and shapes.

Clock-cases, handkerchief-boxes, letter-racks, wall-brackets, and other articles made from cigar-boxes by fretwork.

THINGS FOR GIRLS TO DO

HOW TO MAKE A GIRL'S WORKBOX

HAVE you ever thought of the joy it brings to have a real workbox of your own? Let us try to learn to make a box like the one in the picture.

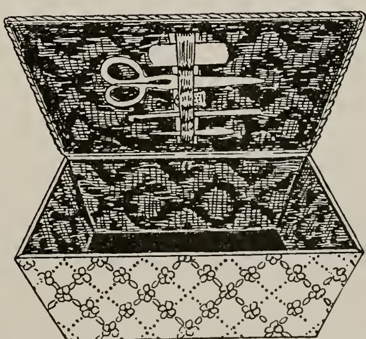


The pattern of the girl's workbox

Take a piece of cardboard thick enough to make a firm foundation, and on this draw a pattern similar to the above, enlarged to the size desired for your box. Cut the cardboard all round the outlines of the diagram. Bend the four pieces which are intended to form the four sides. Do this while following the lines carefully, so that the bottom of the box will be quite even. Straighten the cardboard again, and cut two pieces of cretonne, each one covering entirely the piece of cardboard which includes the bottom and sides of the workbox. Cut the material about a quarter of an inch larger all round than the cardboard, to allow for turning in the edges, which otherwise would fray and look untidy; then glue (or overcast) the cretonne on the cardboard, back and front. When this is done, let it dry for one day.

Then bend your covered cardboard as you did before. Join the corners A together by sewing the cretonne on the two sides with over-and-over stitches, using a needle with strong thread to secure the corners, top and bottom, very firmly. The same thing must be repeated in the corners marked B, C, D.

The workbox now stands, is covered and lined. Some cord sewn round the foot of the box will make a neat finish and slightly raise the box. Now the cover must be made. Cut a piece of cardboard to fit exactly the top of your workbox; then, before putting on the cretonne as you have done on the other part, put a layer of cotton to form padding, and cover it over with the material. Do this on both sides of the cardboard, taking great care to turn the edges in, as described for the other part of the box, before gluing the cretonne down. A strip of material is fixed on the inside of the lid, and sewn at regular intervals, to receive a thimble, a pair of scissors, crochet needle, and other things. The cover is then put on the box part by slipping two small pieces of cretonne under both cover and back of box, one on each side, to form hinges. These are then sewn very firmly, so that the lid can be opened and closed.


The workbox lined and ready for use

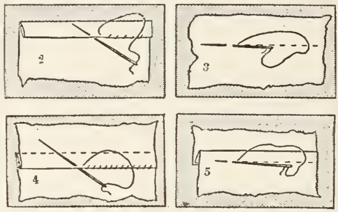
HOW TO USE THE NEEDLE

NOW that we can make a work-box of our own—we must find out how to use it. We are going to dress a doll. We shall cut out the clothes and make them as our own clothes are made. First we shall make the little underclothes, one by one, and then the frock. But before we can do anything at all we must know how the different stitches holding the pieces together are made.

We all think that it is the easiest thing in the world to thread a needle, but the right way to do it is to thread it by the end just cut off the spool, making a tiny knot at the other end. If the cotton is put through the needle at the opposite end all the gloss goes out, knots, and breaks off very easily. Always choose a needle that is just a little thicker than the thread. This will open the material enough for the thread to come through without any unnecessary tugging.

The left hand holds the piece of material between the thumb and first finger, letting it fall loosely over the back of the hand, the little finger just holding it in place. The right hand holds the needle and pushes it in and out of the material, a thimble on the third finger helping to push the needle through. The width of the first fold of a hem should be about one-third the width of the hem required, but in very narrow hems the first fold is the same width as the second. If, however, you intend to sew very fine material, such as muslin, the fold must be the same size as the hem, otherwise the rough edge will show through.

When you have decided what the size of the hem should be, turn the double fold and press it down firmly with your nail, then tack it, with long, even stitches. This will save time, for the hem will keep pressed down in position, and it will help to get the work straight and even. The needle is then put in the material, as you can plainly see in the picture (2), the stitches being done from right to left in a slanting position.



These sketches show you how to make the different kinds of stitches. 2 is a hemming stitch, 3 running, 4 running and felling, and 5 a French seam.

There are many different kinds of stitches, but for our present purpose it is only necessary to know a few of them. The running stitch (3), is one of the most useful to learn, for it is with this stitch that seams are made and materials gathered.

If you are anxious to learn how to do really beautiful sewing, try first on fine canvas, or on any other very coarse material, where the threads can be easily sewn, taking two threads on the needle and going over two. You will be surprised to find how easily the hand and eyes will be trained to work evenly and regularly, until you can work quite pretty little stitches on any material without counting the threads, which is always a slow and tedious method of working.

When you can do the hemming and running stitches quite evenly, you have mastered the most difficult part of sewing, for all the other stitches are more or less made from these two.

If you look at picture 4, for example, you will see a little pattern of running and felling, which always looks full of difficulties to little girls, although it is simply running and hemming.

Two pieces of material are put close together, the back piece slightly overlapping at the top to allow for the folding over of the raw edge, and joined together, on the wrong side, by running stitches. The material is then opened under the seam, laid flat, and the two edges folded over like an ordinary hem.

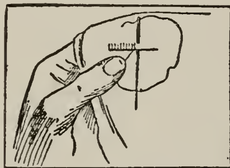
A glance at the picture will show the work far better than it can be explained.

The easiest way for little girls to do running and felling is by French seams. It will probably be the most popular way of doing the seams in dolly's underclothes. If you look at the picture (5) you will see that this kind of seam is simply a double row of running stitches. The first row is done in the ordinary way, then the raw edges are cut as short as possible, and the seam turned inside out, a second row of stitching giving perfect neatness in the finished work. Remember, however, when doing these seams that the first row of running, instead of being done on the wrong side, as for running and felling, is always done on the right side, the second row putting the first one out of sight.

Gathering is done with exactly the same stitches as running, only it must be done with strong thread so that it will not break. The thread is pulled to gather the fullness. No knots or joins must be allowed in the thread, or it will not come through the material to form gathers. Measure the piece of material you want to gather, and take a long enough piece of thread to leave two or three inches to take hold of when you want to draw it. It is always better to do two or three rows of gathers in case one should break, besides giving more evenness and regularity to the gathers.

If the gathers are done on fine material for underclothes when the thread has been drawn, a coarse needle should be used to stroke down the material between each gather.

Buttonhole stitches come next, and these are by no means too difficult



6. Buttonhole stitches

to be attempted. They are really quite easy when you know the way. Try first on a piece of canvas or coarse flannel, and make even and regular stitches quite close to each other. The picture (6) shows just how the stitches are made. Let the thread go under the point of the needle and pull the needle down gently, letting the thread cross over itself where the needle came out. If you follow these directions, and look at the picture, you will find the stitch so easy that you will really be surprised.

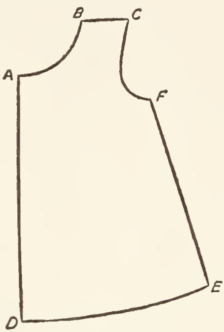
THE DOLL'S FIRST LITTLE GARMENT

WE HAVE learned how to do the different stitches that are needed, so now we should be able to undertake the fine stitching for the garments that we are going to make.

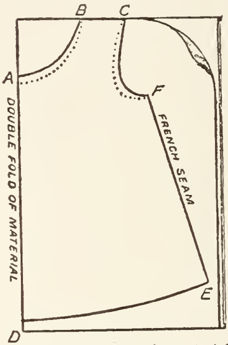
We will start with the little chemise. If you look at the picture (1) you will see that the pattern is quite simple, and very easy to cut out if you read this article carefully.

Draw the pattern to fit the size of your doll on a piece of paper, and mark it A, B, C, D, E, F, like the sketch. Nearly all patterns are cut out in halves—that means that nearly all garments have, of course, two sides, or two parts, which are exactly alike, and it is far easier to get these exact if we double the material, lay the pattern on it, and cut them both at once. This is why we always, or nearly always, speak of a pattern as being *half the back* or *half the front*, and so on. Take a piece of fine muslin, or, better still, nainsook, twice the length and twice the width that you want the little garment to be, allowing enough over for seams and hem. Now fold the material in half, and then fold it in half again. When you have done this the shape of the material should be *as it was before*, only smaller.

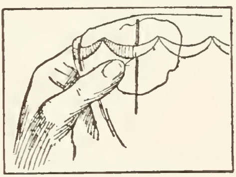
Before going farther be sure that the two single folds of the material are at the top, and the double fold at the side. If this is not quite clear to you, look at picture 2 which shows the material folded. Lay this down on the table in the position shown in the picture, and lay the pattern on it. Pin the pattern to the material before it can slip out of place; then take a pair of scissors and cut all round the outlines of the pattern, except the parts between B and C (this is the shoulders), and between A and D (this is the middle of the chemise, as you will see when you open the material out after it has been cut).

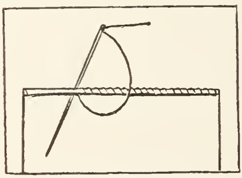


1. How to cut out the pattern



2. Laying pattern on the material


3. Buttonhole scallops


4. The whipping stitch

When you are cutting remember to leave half an inch for the double seam under each arm, and an inch and a quarter for the hem at the bottom.

Take off the pattern and unfold the material. The two sides of the little garment are now shaped and held together by the uncut folds of the shoulder. If you look at your own little chemise you will find that the front of the neck is cut lower than the back. Now turn to the picture (2) again, and you will see that there is a dotted line below the one between A and B. The line between A and B represents half the back of the neck, and the dotted line half the front. So to get the front, take your scissors and cut out the material a little, being careful to slope out more at the center than at the sides. Then slope out each little sleeve (between C and F) in the same way.

Before starting the sewing we must be sure that our hands are spotlessly clean, for on its neatness and cleanliness depends the success of our work. To look well, needlework must be kept quite fresh, or its charm will be gone, however neat the work may be.

Thread a short needle and begin with the seams on each side, joining them either by running and felling them, or by a French seam.

The next is the hem at the bottom. Turn up the material about 1¼ inches. You will remember that we allowed an inch and a quarter when we cut the material. The quarter of an inch is for the first little fold, and the inch will be the width of the hem. Measure an inch and a quarter all round, turn this down and tack it to keep it in place. A good way to measure the hem and to be certain that it is quite even is to get a piece of stiff paper—or a visiting card is better—measure an inch on it, snip it with the scissors to mark it, and use it as you would use a tape measure. When your hem is even fold the rough edge under a quarter of an inch, and tack it again, and then hem it round with neat little stitches.

If we have been practicing all the stitches which we learned, we shall be able to do some small buttonhole scallops round the neck and sleeves, in which case we shall have the daintiest little ornament that one could wish for. If you look at picture 3 you will see how the material is marked in scallops all round for the button-hole stitches to be worked on. The picture shows how the stitches should be narrow at the top of each scallop, and get wider in the middle. If you cannot get this quite even, draw a faint line, like you will see in the picture, and work over it.

But if this is too difficult we can make a little hem and sew on the end of it a piece of pretty Valenciennes lace. As the neck is round, and not straight, it will not be very easy to fold the hem in the usual way; but if you will try to roll the edges and make only a tiny hem, you will find it will not be nearly so difficult.

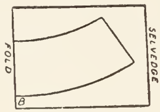
5. The finished garment

Now for the lace. This should be first gathered and pulled up, so that it makes a little frill. When the lace is pulled up full enough—do not let it be too full—sew it on to the edge of the hem with tiny whipping stitches. In sewing the lace to the chemise, do not put the two back to back and then sew, but draw them together as you would sew together the two edges of a hole in a glove. This is the only way to get the lace to set quite flat.

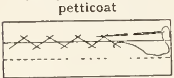
And now your little chemise should look just like the one shown in picture 5.

THE LITTLE PETTICOATS

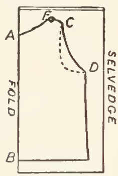
THE next little garment we will make is the flannel petticoat. The pattern of this is very easy, as we can see from pictures on next page. Picture 1 shows half the pattern. Cut your pattern, and lay it on a piece of soft, fine flannel which has been folded in half, taking care that A B lies against the fold. Cut all round, *except between A and B*. To make the back seam, join the two edges as for running and felling, but instead of felling the edges, turn them over, and fasten them by herring-boning them "*raw-edged.*" Leave a placket-hole at the top and make the edges neat by two tiny hems, herringboned, like the seam, to keep them flat. When you have gathered the material, regulate the gathers, so that the front of the petticoat is nearly flat, and the fullness is at the back.



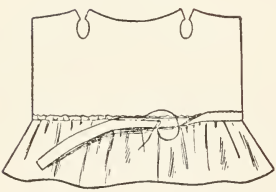
1. Pattern of flannel petticoat



2. Herringbone stitch



3 Pattern of bodice



4. Fastening bodice to skirt

5. The flannel petticoat

6. The white petticoat

The next thing to do is to make the little bodice which has to be joined on to the petticoat. Look at picture 3, and you will see half of the very simple outline of the pattern needed to make this bodice. It is in one piece, and needs no seam except the tiny ones on the shoulders—that is, between E and C.

After you have drawn the design the right size to fit your doll, fold the piece of flannel in half and put the edge of the pattern marked A B on the fold of the flannel. Then pin it, and cut along the lines of the pattern, except between A and B, leaving enough for the turnings.

The dotted line in picture 3 is to show where to slope out the material for the front of the armhole.

After the seams on the shoulders have been done, either with a French seam or running and felling, the little bodice must be finished off at the top with buttonhole stitch to match the bottom of the petticoat. To make the material strong at the back to hold the buttons and buttonholes, which have to be sewn next, a little hem, herring-boned, should be made on each side. If we have cut our pattern correctly, we shall find that we have quite enough material for this without adding any more. When the bodice is finished, the lower part of it is run on to the gathered skirt.

Join the bodice to skirt, by running stitches, as picture (4) shows. But it would be very untidy on the wrong side if we left the raw edges like this, so to make it neat and dainty, a strip of nainsook is run along the gathers, and then turned over and neatly hemmed down just above. But the stitches must be very tiny ones, because they will show on the right side.

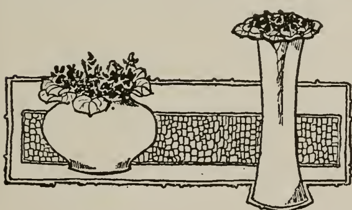
Trim the raw edge of the skirt part with buttonhole stitches, put on another button and buttonhole to fasten the waist-band, and your little flannel petticoat is finished, and will look like picture 5.

The white petticoat, which goes over the flannel one, is cut and made in very much the same way. The only difference lies in cutting out the skirt part of the trimming. The bottom should have two little tucks and a narrow hem, edged with tiny Valenciennes lace. These tucks and the hem will take up about one and a half inches of material, so when we cut out the skirt part of the white petticoat it must be longer than the flannel one. No pattern is needed. It is simply a *straight* piece cut about one and a half inches longer than the flannel one.

But the important thing to remember is to cut it "on the straight," not "on the bias," like the flannel one is cut. Material cut on the bias pulls very easily, and is difficult to tuck. Material that is cut on the straight—that is, in a straight line with the selvedge—is firmer and keeps its shape much better. The reason why we cut a flannel petticoat on the bias is, because it sets better and is less clumsy round the hips, for flannel is a clumsy material. The seams of the white petticoat should be run and felled, not herringboned.

ARRANGING FLOWERS FOR THE HOUSE

THE world has paid every woman a charming compliment. It has credited all of us with the ability to make our surroundings beautiful. Have you not read in many books that the heroine possessed a magic touch? When she had been there the room seemed to show an extra daintiness, the place wore an added charm, an air of comfort and coziness that it did not possess before. But, unfortunately, the novel gave no precise direction as to how she did it.



This shows the right and the wrong way to arrange violets and flowers like them. They should be loosely arranged in a low vase, and not cramped up in a high vase where they can hardly be seen.

These things are not arrived at by instinct. The good fairy who deals out the birth-gifts is not so lavish as we are led to suppose, and seldom gives to anyone so big a gift that there is nothing left to learn. She just gives a little bit—just enough to show it is there—and one has to learn the rest.

We shall not be able to learn here everything that our favorite heroines are supposed to know, but only a few things about one simple part of the subject—how to arrange flowers.

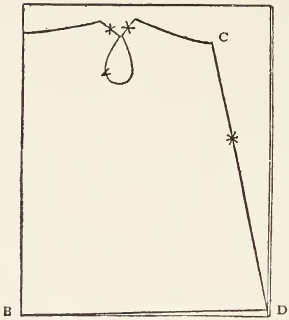
We wonder if you have ever thought that the size, shape and color of the vase is a most important point? For instance, daffodils, which are heavy flowers, should always stand in strong china—for preference, green glazed ware. There is something so strong and sturdy about their growth that they need a good support and plenty of water; so don't put them into frail china vases that will topple over with a breath of wind because they are top heavy.

Also remember how the daffodil grows. How many leaves go to one daffodil? Hundreds! Well, you cannot get hundreds into a vase, but you can get a good many, and you will find the flowers look far finer with a plentiful supply of leaves, because—and this point applies to every kind of blossom—they *grow like that.*

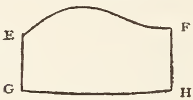
THE DOLL'S LITTLE FROCK

THE little frock illustrated is a simple one. It is made entirely in one piece with only two tiny seams on the shoulder and one in the center of the back. The two armholes are for the little puff sleeves which are also made in one piece with a little seam under the arm. The first thing to do after cutting is to make the seam at the back. This is marked C D in the picture. A little French seam such as we have already done for the underlinen will do very well for this frock, especially if you have been able to coax mother to give you a piece of Japanese silk, or some other thin material.

Do not make a seam at the back right up to the top of the neck, but leave a placket-hole rather more than half-way up, just about where the star is marked on picture (1). Three or four little buttons and buttonholes are needed to close the frock. The hem should be about two inches wide all around with a quarter of an inch turned inside. The neck part is simply gathered into a little straight band which is first run edge to edge with the main part of the frock and then hemmed over the gathers. If this little band is made broad enough it can be doubled over to form a little turn-down collar, which may be ornamented with



1. Pattern of the frock



2. Sleeve pattern


3. Back of the frock

feather stitching, while a lace frill may be added to make it daintier. A wide tape sewn inside at the waistline rather low down, will, if sewn top and bottom all round, act as a slot in which a fine silk tape may be put through to gather the little frock as picture 3 shows.

The pattern of the little sleeve is plainly shown in picture 2. The part between E and F in the picture is the top and when gathered, and the thread pulled up, will form the little puff.

Join the line E G to F H by a French seam and you will begin to see the shape of the sleeve. The top part as we have said, is gathered drawn up, and made to fit the hole left for it in the frock. The side marked F H to put under the arm and the sleeve seam is joined to the notch seen in the pattern. Arrange the fullness to come at the top of the sleeve on the shoulder. The bottom of the sleeve—that is, the part between G H in the picture, is also gathered and then put into a straight band of material which is made large enough to turn over just like the little collar. This too is trimmed with a row of feather stitching.

The little frock shown in the picture has what is called a long waist—that is, the waist trimming is arranged to come much lower than the doll's real waist.

HOW TO MAKE OUR OWN ZOO

A LITTLE while ago most of the creatures in our Home Zoo were lying together all in a heap at the bottom of somebody's piece-bag. They did not look much like animals then, but that was before they were touched and brought into

Animals to make at home

Some members of the zoo

shape by the wonderful fairies Needle and Thread. Our kitten was just a bit of black plush left over from the trimming of a coat; our fierce lion was a corner of fawn-colored, smooth-faced cloth from a tailor-made suit; our fat pig and dear little white bunny were odds and ends of eider-down; and our curly dog was a scrap of imitation astrachan from somebody's winter jacket. But we just cut them out, and sewed them together, and fed them well on wadding, and here they are—all that you see in the picture, and many more. Making one's own Zoo is great fun. It is so nice to have the animals to play with. They will all stand up; and if their feet are glued to a small stand, with wheels—such as any boy can make—little children will be delighted to draw them about. If they are very nicely made they are quite pretty models, and will readily sell at a bazar.

How the cat looks when made

But before we start to make them, there are a few things which we must always remember if we want really to succeed. If we number them it will help us to remember.

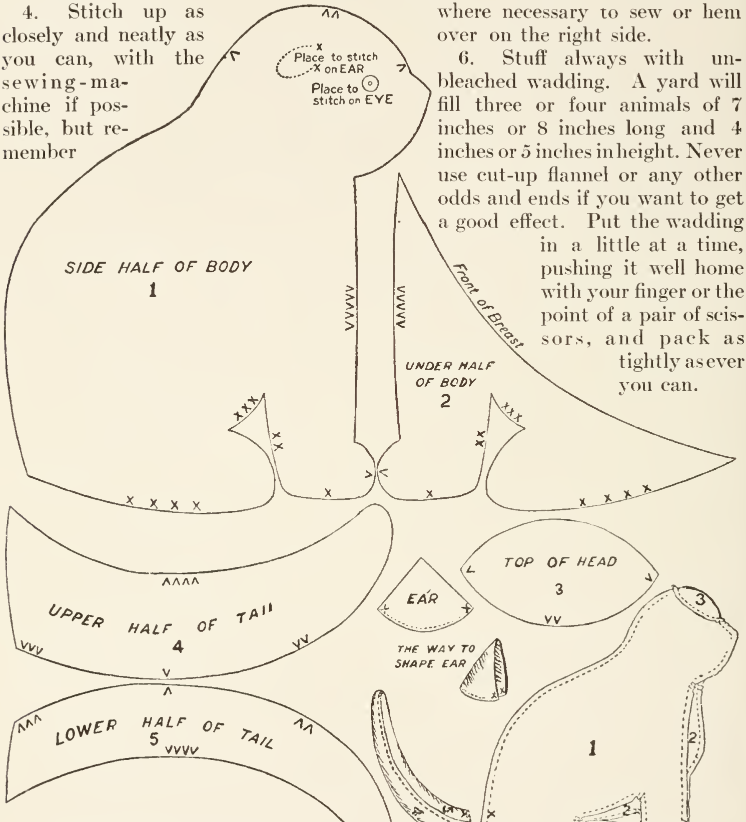
1. The best materials are tightly woven stuffs that are plain on one side and fluffy or shaggy on the other. Thin and loose cloths that easily fray are troublesome. Beaver cloth, all imitation furs—if they are not too thick—eider-down, canton flannel, plush, and velveteen, all make up splendidly.

2. In cutting out, first note which way the pile, or "nap," goes, and take care to place the pattern so that it will stroke from the head to the tail, as in nature.

3. All the patterns are cut out in halves, so that you will have to double

the material. We shall understand this better later. But be very careful to see that the two halves face each other, and cut out with neatness and exactness, making the pieces all fit one another precisely.

4. Stitch up as closely and neatly as you can, with the sewing-machine if possible, but remember



Plans for making the cat shown on the previous page

that very firm, close seams are most important.

5. All animals have their principal seams sewn on the wrong side; but if the cloth is thick and firm, with a good nap, some parts—such as the holes where the legs are fastened in, and sometimes the legs themselves—may be sewn raw-edged on the right side, and the nap at the margin pulled over the stitches to hide them. Thinner cloth must be turned in where necessary to sew or hem over on the right side.

6. Stuff always with unbleached wadding. A yard will fill three or four animals of 7 inches or 8 inches long and 4 inches or 5 inches in height. Never use cut-up flannel or any other odds and ends if you want to get a good effect. Put the wadding in a little at a time, pushing it well home with your finger or the point of a pair of scissors, and pack as tightly as ever you can.

Now we may start on our first animal—the cat. Gray velveteen or plush makes the prettiest cat, but black will do. The cat, when cut out, is in eleven pieces—namely, two upper halves, two under halves, two pieces, upper and under, for each of the ears, the upper and under halves of the tail, and a lemon-shaped piece on the top of the head. We cut out the pieces to the shapes shown in the plans, which we can trace on thin paper. Let us begin with the side half of body which is marked 1. We cut out two pieces this shape, making them exactly alike. We cut out two pieces of the under half of body marked 2 in the picture, then one piece for the top of head, marked 3, one tail piece marked 4, and another tail piece marked 5, and, finally, two ears to the shape given in the picture. We must remember to make every piece the size given in the pictures.

Now we are ready to sew the pieces together. The pictures are marked with V's and X's, and these show what pieces are to be sewn together. The piece marked VV is to be sewn to the other piece marked VV, and so on. We begin by stitching the under halves on to the upper ones, being careful to stitch very closely round the toes. Next stitch up the tail, turn it, and stuff it. Stitch on the lemon-shaped piece to the top of the head in the position shown in the pattern. Sew up the upper animal, beginning at the throat and going over head and back, and ending at the tail. Be careful to keep the halves in proper position.

Now turn the cat and her four paws, and begin to stuff her—first the head, then the paws, then the body. When she seems nearly fat enough, begin to sew up at the tail, and work along, poking in more stuffing as you see it is needed, until you finish up under the chin. The two front legs will probably have to be caught together with strong thread to make pussy sit up properly, and her tail, hemmed at the base, should be curled round her toes, so as to give a natural position.

The ears must be made and turned, after being fastened neatly in the right position, and the two outer edges folded over to meet in the middle. Then you will have a pretty little ear to sew on in position. Beads or sequins make bright eyes; but, if the cat is to be a toy for a young baby, black worsted eyes, just stitched, are safer. A nose and mouth may be also marked in worsted, as here shown, and bunches of white thread can be sewn on for eyebrows and whiskers.

If you finish up by marking the "tabby" pattern in ink, copying from a real cat, and brush the stiffness out when dry, you will find you have made a very charming cat.

COLLECTING FERNS FOR A ROCK GARDEN

NO GARDEN is complete without its ferny nook, and any ugly old corner can be made beautiful in a short time by planting ferns, the graceful fronds of which will, when they unfold, hide every trace of ugliness.

Almost any time of the year we can go on a fern-hunting expedition, and very enjoyable such an excursion is, especially in the autumn, when the ferns appear in all their verdant glory and rich plumage.

No matter where we may live, in or out of a big city, east or west, north or south, inland or by the sea, we are sure to find, within an accessible distance, some spot that is given over to the fern family, and if we are careful we can get new plants for our rockery or shady corner without injuring the countryside in any way.

Hart's-tongue Maidenhair spleenwort

Common polypody Lady fern

Among the rocks by the seashore, in the green lanes, by the side of the meadow, on the moorland, by the banks of the brook or stream, in the ditches by the road, and among the shadows of the wood—all these are places where ferns may be found free and flourishing.

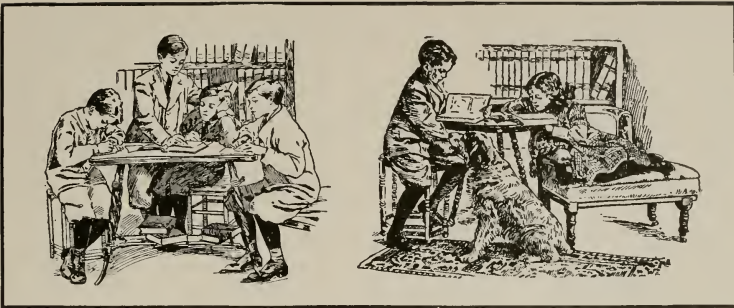
As equipment for a fern-hunt we need some pieces of brown packing-paper or newspaper to wrap the roots of our specimens in, a small garden fork and trowel, and, if we are intending to bring home very many plants, a bag or wicker basket.

In selecting plants, it is wise to take the smaller specimens; they can be removed more safely and easily than larger plants and they are easier to carry home. The earth round the plant selected should be loosened with the fork, and then the fern taken up with the trowel with as little disturbance to the roots as possible. Of course, it is essential that the whole of the roots should be taken, and so we must dig at some distance round and under the plant. The earth adhering to the roots should not be removed. Injury to the root will result in a dwarfed and sickly plant, when the fern is transplanted and made to grow in the garden.

Having freed our specimen, we should place a little damp moss round the roots, wrap the specimen up in paper, and place it carefully in the bag. If it is not convenient to plant them out on arriving home, we can keep them healthy and fresh for several days by laying them in a shady place and occasionally sprinkling the enwrapping moss with water. This plan enables us to bring home safely specimens gathered on a summer holiday.

Of course, if we want to get the best value out of our specimens, we should carefully note the situation and surroundings of each, and try to reproduce these as nearly as possible in the garden.

Rock ferns are more difficult to gather, and, in order not to disturb the roots, it is often necessary to bring home with us a piece of the rock in and round which are the delicate roots.



STORIES AND PLAYS

MASTER SELF

"THERE was once a lit-tle boy," said Mam-ma, "and he loved Some-bod-y ver-y much. It is n't a ver-y large Some-bod-y, but it has bright blue eyes and curl-y hair."——"Why, it 's me!" said Char-lie. "It 's me, my-self."

"So it is," said Mam-ma, laugh-ing. "And it 's 'Mas-ter Self' whom Char-lie loves best. He even does n't love Sis-ter so much as 'Mas-ter Self.' So he keeps all his pret-ty toys and does n't give them up. He loves 'Mas-ter Self' bet-ter than Mam-ma, for when Mam-ma says 'Go to bed,' and 'Mas-ter Self' says 'No,'—Char-lie likes best to please that naught-y 'Mas-ter Self.'"

"I wont please 'Mas-ter Self,' said Char-lie, and he kissed Mam-ma, and said "Good-night." Next day, Mam-ma gave Char-lie a bright, new ten-cent piece, and said he might go with Nurse to buy some can-dy.

When Nurse and Sis-ter were read-y, and Char-lie had taken his lit-tle stick, they set out. Char-lie was think-ing. He was think-ing ver-y much, and he was say-ing to him-self: "I don't love 'Mas-ter Self.'"

He walked qui-et-ly by Nurse's side. Now and then he looked at the mon-ey in his hand; it was ver-y bright and ver-y white. It seemed a long way to the can-dy store.——"What will you buy, Char-lie?" asked Nurse.

"Some can-dy for my-self," said Char-lie, as they reached the Park.

"Keep close to me while we cross the road," said Nurse; but just then Char-lie pulled her dress and whis-pered: "Look, Nurse! Look there!" and Nurse saw a lit-tle girl stand-ing near a tree, a-lone and cry-ing.

"What's the mat-ter with her, Nurse?" asked Char-lie.

"I'll ask her," said Nurse. "What are you cry-ing for, dear?"

But the lit-tle girl on-ly cried the more, and Char-lie went close to her and said: "What's the mat-ter, lit-tle girl?"

The lit-tle girl could not speak, she was sob-bing so much. "Don't cry," said Char-lie, in great dis-tress. "It makes me want to cry too."

"Oh, dear! Oh, dear!" said the lit-tle girl. "I have lost my mon-ey! All my mon-ey." But soon she be-gan to tell Nurse how it was. She was go-ing to get some bread, and she had the mon-ey in her hand,—"and," said she, "a boy pushed me, and I fell, and lost my ten-cent piece, and I can't buy the bread, and Moth-er will be so an-gry."

"I'm glad I did n't lose my piece," said Char-lie, squeezing it hard.

"I am ver-y sor-ry for you," said Nurse. "If I were you, I 'd run home and tell Moth-er."

"I can't! I can't!" cried the lit-tle girl. "It was all Moth-er had, and we 're so hun-gry!"

Char-lie held his mon-ey tight-ly. What was he think-ing of, all the time? He was say-ing to him-self: "I don't love 'Mas-ter Self.'" He pulled Nurse's dress, and said: "Nurse, can't you give the lit-tle girl some mon-ey?"

"I have n't my purse, dear," said Nurse.

The lit-tle girl moved a-way, cry-ing. Char-lie walked be-side Nurse. They were near the can-dy store. He could see the sweets in the win-dow, —sticks and balls and creams! Char-lie turned his head. He saw the lit-tle girl look-ing back too. She was still cry-ing. Char-lie pulled Nurse's dress. "Nurse," he said, "I want to turn back."

"What do you want to turn back for?" asked Nurse. "Here is the store."

Char-lie raised him-self on tip-toe to get near-er to Nurse's ear, and whis-pered:

"I want to please the lit-tle girl and not 'Mas-ter Self'!"

Nurse knew what he meant. She turned back. Char-lie looked once more at the can-dy store, then he ran a-cross the street. When he came close to the lit-tle girl, he held out his bright ten-cent piece and said: "It is for you, and not for 'Mas-ter Self'!"

The lit-tle girl stopped cry-ing and be-gan to smile; then she tried to say "Thank you," to Char-lie; but Nurse said: "Run, now, and buy your bread," and she ran off, aft-er look-ing back to nod and smile at Char-lie.

But Char-lie was even hap-pi-er than she. He walked brisk-ly home and sat on Mam-ma's lap, and told her all a-bout it. Mam-ma kissed him, and said: "Is n't Char-lie hap-py now?"

And Char-lie said: "Yes; be-cause I did n't please 'Mas-ter Self.'"

THE THREE BEARS

GOLDILOCKS TOOK UP THE SPOON AND ATE UP ALL THE BABY BEAR'S DINNER

THREE bears lived in a house in a wood. There was the father bear, the mother bear, and the baby bear. The first was a great big bear, the second was a middle-sized bear, and the third was a tiny wee bear. In the kitchen was a table, and beside the table there were three chairs. The first was a great big chair, the second was a middle-sized chair, and the third was a tiny wee chair.

One day the three bears went out for a walk. Before they started mother bear prepared the dinner, and poured it into three basins. The first of these was a great big basin, the second one was a middle-sized basin, and the third one was a tiny wee basin.

While they were out a little girl named Goldilocks passed by that way, and looked in at the window. She was very cold and hungry, and the bread and honey in the basins looked very tempting. So she pushed open the door and walked in.

"How good it smells!" she said. And she sat down in the great big chair. But it was much too large for her. So she tried the middle-sized chair, but that was not high enough; so she sat down in the tiny wee chair, which just fitted her.

She took up the spoon and soon ate up all the little baby bear's dinner.

When she had finished she began to feel very tired, and thought she would like to lie down. So she went upstairs into the bedroom, where she found three beds. The first was a great big bed, the second was a middle-sized bed, and the third was a tiny wee bed. First she tried the big bed, but it was much too big. So she got out again and tried the middle-sized bed. But *that* was too big, so she jumped into the tiny wee bed and fell fast asleep.

Soon the bears came back, and as their walk had made them very hungry they went straight up to the table.

"Someone's been sitting in my chair," cried the great big bear in a great big voice.

"Someone's been sitting in my chair," cried the middle-sized bear in a middle-sized voice.

"And someone's been sitting in *my* chair," cried the tiny wee bear in a tiny wee voice.

Then they looked into their basins.

"Someone's been tasting my dinner," cried the great big bear in a great big voice.

GOLDILOCKS RAN DOWN THE STAIRS AS FAST AS SHE COULD AND ESCAPED INTO THE WOODS

"Somebody's been tasting my dinner," cried the middle-sized bear in a middle-sized voice.

"And somebody's been tasting *my* dinner and eaten it all up," cried the tiny wee bear in a tiny wee voice.

"Who is it?" cried all the bears together. And they all ran upstairs.

The great big bear ran to the great big bed.

"Somebody's been lying in my bed," he cried.

The middle-sized bear ran to the middle-sized bed.

"Somebody's been lying in my bed," she cried.

And the tiny wee bear called out in a tiny wee voice:

"And somebody's been lying in *my* bed—and, oh, here she is!"

Just at that moment Goldilocks woke up and saw the three bears looking angrily at her. She was so frightened that she jumped up and ran down the stairs as fast as ever she could, and out of the house into the wood, and they never saw her again.

BRER RABBIT AND TAR-BABY

BRER FOX was always trying to catch Brer Rabbit; but Brer Rabbit was mighty pert and spry, and he never let Brer Fox catch him. So Brer Fox pretended to be friendly, and asked Brer Rabbit to come to dinner with him. But Brer Rabbit did not come; he knew what was going to be eaten at that dinner. Brer Fox then thought of something else. He went to work and got some tar and some turpentine, and fixed up a thing which he called a Tar-Baby. He set up this Tar-Baby by the road near Brer Rabbit's house, and laid low beneath the bramble-bushes near by to watch what would happen.

By and by Brer Rabbit came prancing along, lippity-clippity, clippity-lippity, as saucy as a jay-bird. When he saw Tar-Baby he sat up on his hind legs in astonishment.

"Good-morning," says Brer Rabbit, very politely and nicely. "Fine weather this morning," says he.

Tar-Baby said nothing, and Brer Fox he laid low.

"Are you deaf?" said Brer Rabbit. "I can shout if you are."

And he shouted. But Tar-Baby kept on saying nothing; and Brer Fox he winked his eye slowly, and laid low.

At last Brer Rabbit raised his fist and hit Tar-Baby on the side of her head. And there his fist stuck in the tar, and he couldn't pull it away.

"Howdydo?" says Brer Fox, coming out of the bushes. "You seem rather stuck up, Brer Rabbit, this morning."

"Let me go, or I'll strike you again!" says Brer Rabbit. And he hit out with his other hand, and that stuck on Tar-Baby.

Brer Rabbit kicked out angrily with his feet, and they got stuck on Tar-Baby. Then he butted her with his head, and his head also got fixed.

"Howdydo?" says Brer Fox, coming out of the bushes, and looking as innocent as a dicky-bird. "You seem rather stuck up, Brer Rabbit, this morning."

And then Brer Fox rolled about the ground and laughed.

"I expect you'll come to dinner with me now, Brer Rabbit," says he. "We're going to have some nice roast rabbit. You won't play any more tricks on me. You're too saucy by far.

Who asked you to strike up an acquaintance with this Tar-Baby? Now you're going to have a warm time, as soon as I can get some firewood together."

Then Brer Rabbit began to talk mighty humble.

"I don't care what you do with me, Brer Fox," says he, "so long as you don't fling me on those prickly bramble-bushes."

"It's too much trouble to light a fire," says Brer Fox. "I'll have to hang you."

"Hang me, or drown me!" says Brer Rabbit. "I don't mind. But for pity's sake don't fling me on those prickly bramble-bushes."

But Brer Fox wanted to hurt Brer Rabbit as much as he could, so he took him by the hind legs and pulled him off Tar-Baby, and flung him right into the middle of the prickly bramble-bushes. There was a considerable flutter where Brer Rabbit struck the bushes, and Brer Fox wanted to see what was going to happen. By and by he heard someone calling up the hill, and there he saw Brer Rabbit sitting on a log, combing the tar out of his hair with a chip of wood.

"I was bred and born in a bramble-bush, Brer Fox—bred and born in it," says Brer Rabbit, with a laugh. And with that he skipped off home as lively as a cricket.

THE THREE LITTLE PIGS

ONCE upon a time, three little pigs went out into the world to seek their fortunes. The first little pig had not gone far before he met a man who was carrying a bundle of straw.

"If you please," said the little pig, "will you give me some of that straw to make me a house?"

"With pleasure," replied the man.

Away went the little pig with the straw, and built his house.

Now, an artful old wolf who lived close by determined to have the little pig for supper. So when it became dusk he went up to the little straw house and called out:

"Little pig, little pig, may I come in?"

But the little pig knew his voice, and said:

"No, no; by the hair on my chinny, chin, chin!"

"Ho, ho!" cried the wolf. "Then I'll puff and I'll blow till I blow your house in."

And he puffed and he blew, and he puffed and he blew till the house fell down. Then he sprang inside, pounced on the little pig, and gobbled him all up.

The second little pig met a man carrying some sticks.

"If you please," said the little pig, "will you give me some of those sticks to make me a house?"

"With pleasure," replied the man.

Away went the little pig with the sticks, and built himself a cozy house.

That night the wolf came to the door.

"Little pig, little pig," cried the wolf, may I come in?"

"No, no," replied this little pig, as the other one had done; "by the hair on my chinny, chin, chin!"

"Ho, ho!" cried the wolf in a rage. "Then I'll puff and I'll blow till I blow your house in."

And he puffed and he blew, and he puffed and he blew till the house fell down. Then he sprang inside, pounced on the poor little pig, and gobbled him all up.

But the third little pig was exceedingly wide awake the morning he set out on his travels. This little pig went on till he saw a man carrying bricks.

"If you please," said the little pig, "will you give me some of those bricks to make me a house?"

"With pleasure," replied the man.

Away went the little pig with the bricks, and built his house.

Soon the old wolf came along that way, and knocked at the door.

"Little pig, little pig, may I come in?" cried he.

"No, no; by the hair on my chinny, chin, chin!"

"Then I'll puff and I'll blow till I blow your house in!"

But the house was made of bricks, and the old wolf he puffed and he blew, and he puffed and he blew, and still the house stood firm. At last he went away in a rage; but presently he came back again.

"Little pig, little pig, I know a field just down the lane where there are such fine turnips. I'll call for you in the morning and show you the way."

The next morning when the wolf called out: "Are you ready, little pig?" the little pig replied: "Dear me, how late you are! I've been back an hour or more. I'm sure I'm much obliged to you; they were fine turnips!"

The wolf was furious; but, pretending he did not mind, he said, quite pleasantly:

"Do you like apples? I know an orchard down the lane where the trees are covered with fruit. I'll call for you in the morning, and show you the way."

The next morning the wolf got up very early, and walked round to the little pig's house. But the little pig must have got up earlier still, for when the wolf arrived he found him out.

The wolf hurried off to the orchard; but the little pig saw him coming, and climbed up into a tree.

"These are indeed fine apples," he called out, as the wolf came up to it. "Just try this one." And he threw the apple as far away as he could into

THE WOLF CAME BACK AGAIN TO THE HOUSE

"Dear me, how late you are!" said the little pig when he saw the wolf. "I've been back an hour or more. I'm sure I'm much obliged to you; they were fine turnips!" The wolf was furious, but pretended he did not mind.

some long grass. Then, while the wolf was hunting for it, the little pig scrambled down the tree, and ran home.

The wolf did not like being beaten, so the next morning he went again to the little pig's house, and said:

"Little pig, little pig, there's going to be a fair on the village green this afternoon. You come along with me, and we'll both have a fine time. I'll call for you at exactly three o'clock."

The little pig said nothing, but at half past two he started off for the fair. He bought a churn, and was rolling it home, when he saw the wolf in the distance. Quick as lightning the little pig jumped into the churn to hide, and set it rolling down the hill. The hill was steep, and the churn came flying along at such a speed that the wolf became frightened, so he turned back and ran home as fast as he could.

Some hours later, when he felt braver, he went to the little pig's house.

"I was just on my way to call for you this afternoon," he shouted out, "when I met the most awful thing rolling down the hill all by itself. It gave me a horrible fright, I assure you. There must have been a witch inside."

The little pig burst out laughing, and he laughed so loud and he laughed so long that the old wolf got annoyed.

"I was the old witch," said the little pig, as soon as he could speak. "I spied you a long way off, and I jumped inside to save my skin."

This so enraged the wolf that he jumped up on to the roof and began sliding down the chimney. But it was baking day, and the little pig had made a huge fire. Down, down, down slid the wolf; there was nothing to save him. He sank right down into the fire, and was burned to cinders. And that was the end of the old wolf.

THE STORY OF THE DAYS

SUNDAY, MONDAY, TUESDAY, WEDNESDAY, THURSDAY, FRIDAY, SATURDAY

HAVE you ever met Mr. and Mrs. Day? A more useful family you will never meet from one year's end to the other. They are, in fact, the best servants of the human race, and do as much work in their time as anything or anybody on the face of the earth. We must make their acquaintance.

The seven-roomed house in which they live is called "The Week," and it stands in Month Street, which is one of the twelve roads running through Year Town in the wonderful country of Time. We will enter this house and go through the seven rooms together. Mr. Day lives in one room, Mrs. Day in another, and their five children have each a room to themselves. But they are only separated from each other by walls of Sleep, and they talk to each other through the telephone of Dreams.

Now, this is the first room, occupied by Mr. Day, who does less work than the rest of the family, but who is very far from being idle. He puts on a surplice and holds Church services, and he also has to provide the whole of the human race with amusements and recreations. He is the father of the family, and he is known by the name of Sun Day.

"Hullo, Mr. Sun Day! How are you? Glad to see you. But everybody's that, eh? There is no member of your family quite so popular as you are! Come, I hope you are glad to see me, too. I've brought a little friend with me, who wants to know how you

AGES AGO MEN WORSHIPED THE SUN AND CALLED THE FIRST DAY OF THE WEEK AFTER IT

got your name, and to hear something of your history. Do you feel like talking for a few moments?"

"How I got my name? Well, that's an old story, that is. How I got my bad name isn't nearly so old; and how I am getting my good name is quite a new story. Nevertheless, just to oblige your young friend, I'll run the whole three stories into one, and begin with the old one. Far back in the history of the world, young friend, people could see nothing so wonderful, nothing so beautiful, and nothing so useful as the sun. They had in them what is called the *instinct of worship*—that is to say, they had a feeling that there was Something greater, stronger, and more glorious than themselves—Something that they ought to fear, reverence, and worship. The sun seemed to these first people the token or sign of that Something, and they worshiped it. The sun, in fact, became the visible expression of God. Now, when the world got wiser, and men and women knew more about the true God, they still kept the old idea of the heathen in their heads, and called the Christian Sabbath—which means the day of rest—Sunday. They no longer worshiped the sun, but they called the first day of the week after it, and that is how I got my name.

"People loved me then, and I gave rest, and pleasure, and festivity to hundreds of generations. Well, as time passed on, people began to make me anything but a sun-day; they made me a black day. Children were not allowed to play; books and games were put away and locked up in cupboards as something wicked; and all my precious hours were spent in gloom and solemnity.

"Then it was that I got a thoroughly bad name. People said Sunday was the gloomiest day in the week; they ate too much, and sat about yawning and grumbling. Just lately I've reminded them that the Founder of Religion once said: The Sabbath was made for man, not man for the Sabbath. They don't quite understand just yet what that means. Some of them are noisy and wild and foolish on the Sabbath; they have gone to the other extreme. But it will come right soon. People will use me for rest of body and mind in a proper way, and my good name will be restored.

for Moon. She is really Moon Day, the day sacred to the wife of the Sun. In ancient times people called the goddess of the moon Diana, and temples were built for her in nearly every quarter of the world. They used to think that Phœbus Apollo, the Sun God, drove his flaming chariot across the sky by day, and that Diana drove her silver chariot through the sky by night. They loved Diana because she was gentle and beautiful. Woods

MONDAY WAS SACRED TO THE MOON, THE WIFE OF THE SUN, WHO WALKED IN THE WOODS

were sacred to her because she could be seen walking through them. Round cakes were made on her feast day, with candles stuck round them.

"Well, let us pass to the next room and see what Mrs. Day will tell us."

"I've no time to stay to gossip. I'm a busy woman. Everybody knows that I'm the busiest day in the week. It's coming after Sunday that does it. Ah, he's a lazy fellow, my husband is. The mess I have to clear up after him! I don't believe in holidays—except Easter Mondays. Let everyone do his work."

"We mustn't interrupt her," said Mr. Day. "Her name of Mon is short

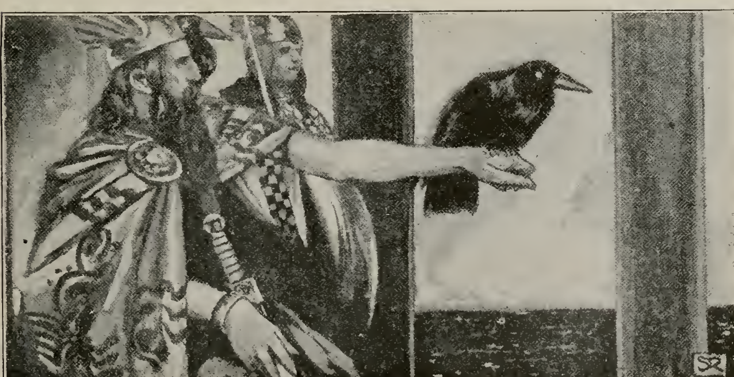
And now we must peep into the room of Mr. and Mrs. Day's eldest son, Master Tues Day. You observe that he has only got one hand, and the story of how he lost his other hand is the story of how he came by his name.

The Norsemen had a god of war named Tyr, and when a terrible wolf-spirit, named Fenris, had to be cap-

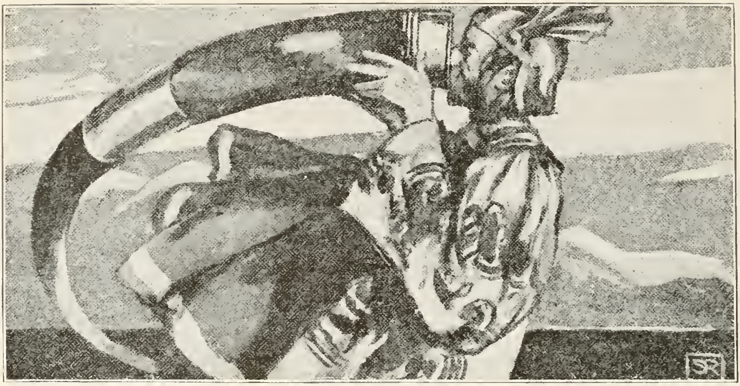
TYR, THE GOD OF WAR, CAPTURED THE WOLF-SPIRIT, AND TUESDAY IS NAMED AFTER HIM

tured, because he was troubling the whole earth, it was Tyr who undertook the dangerous venture. The spirits of the mountains had made a chain out of the hardest things in the world to find—the footsteps of a cat, the beards of women, the roots of stones, the breath of fishes, the nerves of bears, and the spittle of birds. This strange chain could not be broken, and with it Fenris was to be bound.

But Fenris would not allow even this soft-looking chain to be put round his neck, and said he would only suffer it if the gods would promise to take it off again, and would send a god to put his hand in the wolf's mouth. Tyr was the only god brave enough to volunteer. He put his hand in the mouth of Fenris, and Fenris was bound; then, in his rage at being captured, he bit off the hand of the god. It is curious that the French name for Tuesday is Mardi—that is, the day of Mars, who was also a god of war like the Norseman's Tyr, who gives us Tyr's Day, or Tuesday. The second son of Mr. and Mrs. Day is named after



WEDNESDAY IS CALLED AFTER WODEN, WHO SENT RAVENS ROUND THE WORLD FOR NEWS

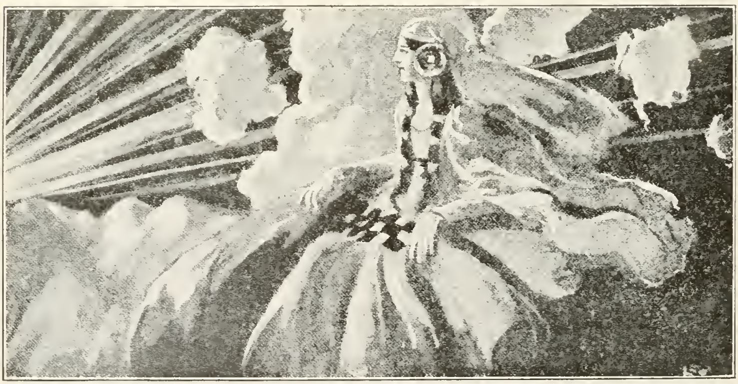


THE MORE THAT THOR, THE GOD OF THURSDAY, TRIED TO DRAIN THE HORN, THE MORE IT FILLED

Woden, or Odin, the greatest god of the Scandinavians. Woden lived in a palace built entirely of gold and silver, which was called Valhalla. Two ravens stood on his shoulders, and when he wanted news of the world he sent these ravens to fly round the earth and bring him intelligence of everything they saw and heard.

Round about him stood maidens with helmets, and spears, and shields, and these maidens, named Valkyries, were sent down to earth to bring the souls of heroes slain in battle to feast with Woden in Valhalla. While they feasted, Woden listened to their stories and drank mead. He never ate anything himself. Our friend Wednes Day is rather odd and capricious in his habits. He sends his Valkyries to bring boys and girls into Valhalla for a half-holiday, but leaves the rest of the world hard at work. But he is a good fellow, and everybody likes him. He lives in the middle of the house and seems to be saying all day long:

"Work away; work away! Sunday will soon be here again."



FRIDAY WAS NAMED AFTER FREYA, THE WIFE OF WODEN, SO THAT SHE MIGHT NOT BE JEALOUS

And now here we are at the fifth room, occupied by Master Thurs Day. Isn't he a big strong, vigorous fellow? If ever you have a hard bit of work to do, start at it on Thursday—the day of strength and power. Thurs Day gets his name from Thor, the strongest of all the Scandinavian gods. Thor had a hammer which no man could lift, a pair of iron gloves, and a belt which, when it was fastened round him, doubled his great strength. But once the mighty hammer was lost, and a giant named Thrym hid it. He said he would only give it up if the goddess Freya would marry him. Thor disguised himself in Freya's dress and went to visit the giant. He received the hammer, and slew Thrym and all the other giants.

The sixth room belongs to Mr. and Mrs. Day's only daughter, Fri Day, named after the goddess Freya, who refused to marry Thrym. How this female Day got her name is rather sad. Woden was Freya's husband, Thor her son; and it was only because she might be jealous that our ancestors named a day after her when they had given one to Woden and one to Thor. However, Friday is a very sacred day, although some superstitious people think it is a day of ill-luck.

And now here is another half-holiday room, Satur Day, who gets his name from the Roman god Saturn, a god who ate his own children. For us Saturday is one of the pleasantest days in the week, although some of the games and feastings of our Saturday crowds remind us of those terrible Saturnalia which disgraced Rome.

SATURDAY IS THE DAY OF SATURN, IN WHOSE HONOR THE ROMANS USED TO FEAST AND DRINK

AURORA

THE STORY OF APOLLO AND LETO

In very early days people, as we now know, had very little true knowledge of the sun and moon and stars; of the sea and the winds and the storms. Indeed, they knew as little of these as they did of the Creation.

To them it was all very, very wonderful, and they thought out wonderful stories to account for what they saw on the earth and in the skies above them.

They knew that when the sun shone, the green grass sprang up; the flowers came; the trees were loaded with fruit, and food was plentiful.

So they began to say to each other, "The sun is our Good Spirit, the Loving One who watches over us and takes care of us."

And so it came about that, by and by, these early people became sun worshippers; they prayed and offered sacrifices to the sun; and after a long time there grew up many stories of the sun.

Here is a story of the Sun God as the early Greek people used to tell it to their little boys and girls:

Once there was only darkness upon the earth. Then a beautiful woman, Leto, came wandering up and down the dark earth, carrying in her arms a beautiful, sunny-haired baby boy.

"Let us dwell here in your land," said Leto to the people. "Let me rest here upon your hillsides. Behold, I bring the light of day to you," she pleaded. "I will bring you power and wealth and rich harvests and beautiful flowers, for the Sun God shall abide in the land which gives me shelter."

"We know," said the king of Crete, "that all these things are promised wherever the Sun God shall dwell; but we are afraid of you; we fear your dark and terrible beauty."

"We know that such a god is promised," said also the king of Athens; "and gladly would our people welcome him. But how are we to know that you are the mother of this radiant god? No, Leto, we dare not open our gates to you. Go hence; we await the coming of Apollo."

And so from land to land Leto wandered, till at last she came to the island of Delos. It was but a barren little island in the midst of a great blue sea. Its shores were rocky; its fields were bare; its mountains black and grim and wild.

And in the island dwelt a king whose people were poor and ignorant. He had neither wealth nor power; and scarcely was the name of this king known among the people of the lands that bound the sea.

"Delos, Delos," cried Leto, when she came to this rocky shore, "listen to the voice of Leto. Give me welcome and I will bring glory and great wealth and power to your people. The island of Delos shall be a temple; and to its altars people from all nations shall come, bringing their offerings. Welcome me, and my child, the Sun God, Apollo, will love you and will abide forever in your land."

Then said the king of Delos, "Leto, it cannot be that the Apollo would care to dwell upon our barren island. Little have we to offer this glorious child of thine; for we have but a rocky soil. The mountains are black and rough. Our people are fierce. They know little of the wealth and glory of other lands. A weary home would this be for a child like the fair Apollo."

"O king of Delos! can you not believe that the promise I make shall be fulfilled?" said Leto.

Then the good king said, "Even though the child shall not remain in this land of Delos; and even though this island has little to offer either to gods or men, let it not be said that we failed to welcome any stranger who came to our shores. Enter, Leto, and rest in Delos."

Then Leto entered. The darkness grew deeper and deeper upon the island and there was stillness even upon the seas. The king and all his people slept, but happy dreams, however, came to them; dreams of glory and power; dreams of beauty and greatness; dreams of light and of a splendor which the earth had never known.

By and by the king awoke. Upon the mountain tops he saw a new, strange light and brightness shining behind the great, dark pillars of rock. Gradually the light grew brighter. And behold, there upon the mountain top stood Apollo, the Sun God, his hair shining like gold in the fresh new light of day.

He smiled down upon the plain, and the plain blossomed into color. Grains grew and waved their happy blossoms in the wind; flowers sprang forth—flowers of richest color and sweetest odors.

For Apollo, the Sun God, had come! He had made his home in Delos; and there was joy in the island from shore to shore.

Under a toadstool
  Crept a wee Elf,
Out of the rain,
  To shelter himself.

Under the toadstool,
  Sound asleep,
Sat a big Dormouse
  All in a heap.

Trembled the wee Elf,
  Frightened, and yet
Fearing to fly away
  Lest he got wet.

To the next shelter—
  Maybe a mile!
Sudden the wee Elf
  Smiled a wee smile.

Tugged till the toadstool
  Toppled in two.
Holding it over him,
  Gaily he flew.

Soon he was safe home,
  Dry as could be.
Soon woke the Dormouse—
  "Good gracious me!"

"Where is my toadstool?"
  Loud he lamented—
And that's how umbrellas
  First were invented.

SIMPLE SIMON met a pieman
Going to the fair ;
Says Simple Simon to the pieman :
" Let me taste your ware."
Says the pieman unto Simon ·
" First give me your penny ! "
Says Simple Simon to the pieman :

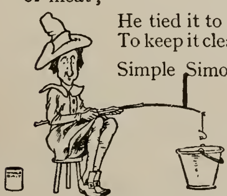
" Indeed, I have not any."

He went to catch a dicky bird,
And thought he would not fail,
Because he had a little salt
To put upon his tail
He went to ride a spotted cow
That had a little calf ;
She threw him down upon the ground,
Which made the people laugh.

Then Simple Simon went a-hunting
For to catch a hare ;
He rode a goat about the street,
But could not find one there.
Simple Simon went to town
To buy a piece of meat ;

He tied it to his horse's tail
To keep it clean and sweet.

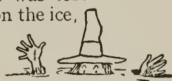
Simple Simon went a-fishing
For to catch a whale,
And all the water he had got
Was in his mother's pail.



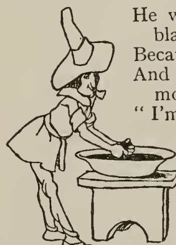
He went to take a bird's nest—
'Twas built upon a bough ,
A branch gave way, and Simon fell
Into a dirty slough.
He went to shoot a wild duck,
But the wild duck flew away ,
Says Simon " I can't hit him
Because he will not stay "

Once Simon made a great snowball,
And brought it in to roast ;
He laid it down upon the fire,
And soon the ball was lost

He went to slide upon the ice,
Before the ice would bear
Then he plunged in above his knees,
Which made poor Simon stare.

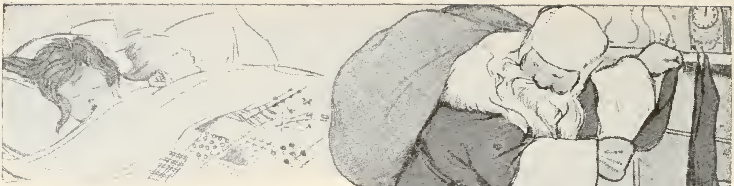
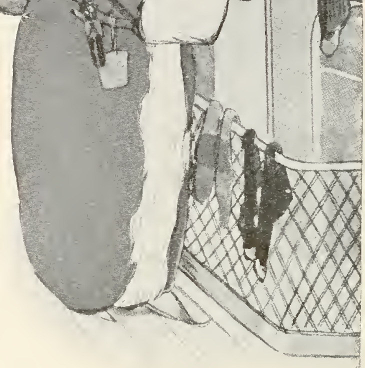


Simple Simon went to look
If plums grew on a thistle ;
He pricked his finger very much,
Which made poor Simon whistle.



He washed himself with blacking ball,
Because he had no soap ;
And then said to his mother :
" I'm a beauty now, I hope."

He went for water in a sieve,
But soon it all ran through.
And now poor Simple Simon
Bids you all adieu.

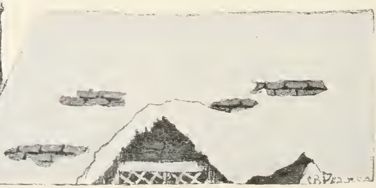
HE comes in the night! He comes in the night!
He softly, silently comes;
While the little brown heads on the pillows so white
Are dreaming of bugles and drums.
He cuts through the snow like a ship through the foam,
While the white flakes around him whirl;
Who tells him I know not, but he findeth the home
Of each good little boy and girl.

His sleigh it is long, and deep, and wide;
It will carry a host of things,
While dozens of drums hang over the side,
With the sticks sticking under the strings.

And yet not the sound of a drum is heard,
Not a bugle blast is blown,
As he mounts to the chimney-top like a bird,
And drops to the hearth like a stone.

The little red stockings he silently fills
Till the stockings will hold no more;
The bright little sleds for the great snow hills
Are quickly set down on the floor.
Then Santa Claus mounts to the roof like a bird,
And glides to his seat in the sleigh;
Not the sound of a bugle or drum is heard
As he noiselessly gallops away.

He rides to the East, and he rides to the West,
Of his goodies he touches not one;
He eateth the crumbs of the Christmas feast
When the dear little folks are done.
Old Santa Claus doeth all he can,
This beautiful mission is his;
Then, children, be good to the little old man,
When you find who the little man is.



THE BATTLE OF BLENHEIM

The great battle of Blenheim, a town on the River Danube, was fought on August 13th, 1704, Marlborough commanding the English army allied with the Germans against the French and Bavarians. It was "a famous victory," but 37,000 lives were lost. The poem was written by Robert Southey, who was made Poet Laureate of England in 1813, though we cannot call him a great poet. By means of a very simple talk between an old man and a little boy and girl, who had found the skull of one of the slain soldiers a hundred years after the battle, the poet shows us what a terrible curse is war.

It was a summer evening,
Old Kaspar's work was done,
And he before his cottage door
Was sitting in the sun;
And by him sported on the green
His little grandchild, Wilhelmine.

She saw her brother Peterkin
Roll something large and round,
Which he beside the rivulet
In playing there had found;
He came to ask what he had found,
That was so large and smooth, and round.

Old Kaspar took it from the boy,
Who stood expectant by;
And then the old man shook his head,
And with a natural sigh—
"'Tis some poor fellow's skull," said he,
"Who fell in the great victory.

"I find them in my garden, for
There's many here about;
And often when I go to plough
The ploughshare turns them out;
For many thousand men," said he,
"Were slain in that great victory."

"Now tell us what 'twas all about,"
Young Peterkin he cries,
And little Wilhelmine looks up
With wonder-waiting eyes.
"Now tell us all about the war,
And what they fought each other for."

"It was the English," Kaspar cried,
"Who put the French to rout;
But what they fought each other for
I could not well make out.
But everybody said," quoth he,
"That 'twas a famous victory.

* * * * * *

"They say it was a shocking sight
After the field was won;
For many thousand bodies here
Lay rotting in the sun:
But things like that, you know, must be,
After a famous victory.

"Great praise the Duke of Marlbro' won,
And our good Prince Eugene."
"Why, 'twas a very wicked thing!"
Said little Wilhelmine.
"Nay, nay, my little girl," quoth he,
"It was a famous victory!

"And everybody praised the Duke
Who this great fight did win."
"But what good came of it at last?"
Quoth little Peterkin.
"Why, that I cannot tell," said he,
"But 'twas a famous victory."

"'TIS SOME POOR FELLOW'S SKULL," SAID HE, "WHO FELL IN THAT GREAT VICTORY."

HOW PETER PAN FOUND HIS SHADOW

THERE was once upon a time a little girl named Wendy Moira Angela Darling. She lived in a house with her brothers, John Napoleon Darling and Michael Nicholas Darling. This house was an ordinary house of brick and slates, but one thing about it was quite extraordinary. It contained a Newfoundland dog whose name was Nana, and this dog acted as nurse to the three children.

Nana was so clever that he never allowed the children to put on a flannel night dress before it was aired at the fire; and he knew how to turn on the hot water when it was bath-time; and however the children might cry that they would not be bathed, or that they would not go to bed, Nana always insisted that they should.

Now Mrs. Darling loved Nana, and she had a particular reason for keeping this brave and powerful dog as the children's nurse. One night, on visiting the nursery, she had seen a strange flitting shape moving quickly to and fro in the dim glow of the nightlight. At sight of Mrs. Darling this shape rushed to the window. Mrs. Darling darted towards it. Just as it sprang into the night Mrs. Darling pulled down the window with a bang. The shape escaped; but something fell on the floor at Mrs. Darling's feet. It was the shadow of this strange, flitting creature. Mrs. Darling put the shadow in a drawer; but she felt very nervous for the safety of the children. She feared that the shape might come back and do them some dreadful harm. The only comfort she had was the presence of Nana in the nursery. The big dog, she thought, would protect her children from all danger. But one night Mr. Darling was rather cross,

Peter Pan saves the children from the pirates and he said it was ridiculous to have a dog for a nurse; and he got so cross at last that he said Nana should sleep in a kennel in the yard. Mrs. Darling pleaded; the children cried; Nana barked. Mr. Darling, however, was extremely cross, and Nana was led away to the yard, moaning and growling.

That night the window was thrust open, and into the room glided and skipped the mysterious shape.

"Where is my shadow?" it cried; while Nana barked furiously outside.

"I can't be happy without my shadow. Tinker Bell, Tinker Bell, where is my dear little shadow?"

Instantly a spot of light flicked into the room, and sprang round the walls, and over the ceiling, and down the beds, and across the carpet, making a tinkling sound wherever it flitted and whenever it settled for a moment. This was the fairy Tinker Bell, a little female fairy. She told the shape where the shadow lay, and soon the drawer was open, the shadow pulled forth, and the shape skipped round the room with delight, singing, dancing, laughing in its joy, while Tinker Bell flashed round the room like a luminous butterfly. But, alas! when the shape tried to make the shadow stick on, it refused, and so all the delight went, and the shape burst into passionate tears.

Just at this moment Wendy awoke. She was not frightened, and asked the little shape why it was crying. Then she asked it its name, and the shape told her that it was Peter Pan. Wendy got needle and thread and stitched the shadow on to Peter Pan, and then Peter Pan danced with joy, for wherever he went the shadow followed him on the floor.

Peter Pan then told Wendy his story. He said that he lived in a place called Never-Never-Land, with a lot of little boys who had all been dropped out of their perambulators by careless nurses; and that they lived with fairies and would never grow up, but for always and always would remain happy boys in this enchanting Never-Never-Land.

He told her that when the first baby laughed, the laughter broke into little pieces, and each little piece became a fairy, and went dancing about the world. But whenever a child says

Statue of Peter Pan in Kensington Gardens, London that it does not believe in fairies, then one of the fairies dies. Peter Pan said it was dreadful for a child to say it did not believe in fairies. There was only one other thing that made them sad, he said, and this was the want of a mother; all the boys in Never-Never-Land wanted to have a mother very much indeed. Wendy asked if there was not a little girl among them who could pretend to be their mother; but Peter Pan shook his head and answered that girls never dropped out of their perambulators, they were far too clever. This pleased Wendy, and she loved Peter Pan.

"Oh, Wendy," cried Peter, "come and live with us and be our mother!"

The two boys woke up. Peter Pan said he would teach them all to fly if Wendy would only come and be their mother. All this time Tinker Bell was tinkling angrily, and telling Peter Pan to come away at once. Tinker Bell loved Peter Pan, and was jealous of Wendy.

When the children heard that they could learn to fly, they were quite excited, and immediately began to spring in the air. But every time, they fell and sprawled on the ground, or bumped flat on the beds.

"You must think beautiful thoughts," cried Peter Pan; and, so saying, soared up gracefully into the air, and sailed noiselessly round the room.

Soon the children learned, and all began to fly round the room with cries of delight. Then the windows opened wide, and Peter Pan led the way into the night; and while Tinker Bell tinkled loudly and Nana barked warningly, the children soared towards the stars.

The boys in Never-Never-Land were beginning to get anxious about Peter Pan, who was their captain. He seemed to be a long time away, and they were frightened of wolves and pirates. While they were wondering what had happened to Peter, they saw what looked to them like a large white bird in the sky.

As they gazed at it, Tinker Bell suddenly shone on the trees, and, tinkling very loudly, told them that Peter Pan wanted them to shoot this bird at once. So they ran and got bows and arrows, and shot them into the air. Suddenly down fell—what do you think?—poor Wendy with an arrow in her breast. Jealous little Tinker Bell was responsible for this awful deed.

But she was not killed. Soon she revived, and then with her brothers round her, and Peter Pan holding her hand, she promised all the boys to be their mother. Then they set to, and built Wendy a funny little house, with the silk hat of John Napoleon Darling for its chimney-pot; and everybody was wonderfully happy, except Tinker Bell, who was more and more jealous of Wendy.

Now, while they were so happy in their house, through the wood came the terrible pirates. The captain of this frightful gang was named Captain James Hook, and a more horrible villain never froze the blood in a child's veins. All his crew feared him and cowered before him. His long black hair was enough to make you shiver; his yellow skin made you go white; his coal-black eyes struck daggers of fear into your heart; but, far worse than all these, more awful even than his cackling laugh and his way of rolling his "r's" so that they sounded like pistols, was his right hand. His right hand wasn't a hand at all, *it was an iron hook.* How he came to have that hook is part of the story.

Peter Pan had tripped the terrible pirate into the sea, and a crocodile, a tremendous *c-r-r-r-r-rocodile,* had

The Darling family at home, showing Michael on his father's back

Peter comes in at the window to look for his shadow

The little house that the lost boys built in the woods for Wendy snapped off his hand and part of his wrist. Nor was this all. The crocodile enjoyed the captain's hand and wrist so much that it wanted more, and so it haunted the captain wherever he went, longing to eat another bit of him, and dreaming of the happy day when it would gobble him all up. The captain always knew when his ferocious enemy was near, because on one occasion it had swallowed an alarm clock, and the ticking of this clock could plainly be heard through its skin. But the captain feared, because he knew the clock would one day run down, and then the crocodile would be able to steal upon him unawares.

You can imagine how this pirate hated Peter, the cause of all his troubles, and how he longed to slay him.

One day, when some friendly Indians were guarding the boys, up came the pirates and made a great slaughter of the poor redskins. The boys did not hear the battle, for they were very interested in something that Wendy was telling them underground.

Wendy, you must know, had become the mother of these boys, and they all did exactly what she told them, and all adored her, because it was so delightful to have a mother after having lived so long without one. After she had seen mermaids and a bird that gave up its nest for Peter Pan to use as a boat, she settled down to be a real practical mother, giving the boys their medicine, teaching them how to behave nicely, and tucking them all up nice and comfy in their beds. Considering that she was only nine years of age, Wendy made a splendid mother.

Well, on this night, Wendy was telling them a story about her own father and mother—a beautiful story which showed how that mother and father must be weeping for their lost children. As she was finishing, John Napoleon and Michael Nicholas sprang up in their beds, and said:

"Wendy, we must go back!"

"Yes," answered Wendy, "we must go back."

You can imagine how dreadfully sad all the motherless boys were when they heard that Wendy was going home. They cried so much that at last she told them they might come back with her and her brothers, and live in their house, and have Mr. and Mrs. Darling for their father and mother. All the boys accepted this offer with delight except Peter Pan. Peter Pan said he did not want to grow up. He did not want to live in a real house and go to school. He wanted to live always in Never-Never-Land, with the fairies and birds and mermaids. In his heart he was terribly sad at losing Wendy, whom he loved very much indeed; but he refused to go away and grow up like an ordinary boy.

So they all said good-by to Peter Pan, and one by one went up the narrow tunnel which led from their underground home to the forest and the night. Wendy was the last to go, and before she went she poured out some medicine for Peter and made him promise her that he would take it when he woke up in the morning.

But instead of kind redskins keeping guard, the pirates were there. The boys were seized one by one as they stepped on ground; a rough hand was clasped over their mouths to prevent them from crying out, and they were carried away prisoners to the pirate ship with Wendy.

Peter Pan lay asleep in his bed. The rest of the boys were on board the pirate ship. Peter Pan was alone, and asleep.

Captain Hook was creeping to the hole above. Now was his chance to slay his enemy.

Noiselessly the pirate chief crept down the hole. He arrived at the door, and peeped over the top. Peter Pan was fast asleep. He tried to open the door, and failed. Again and again his hook fumbled at the latch, but failed. Peter Pan was safe. But no! The terrible captain espied the glass of medicine left by Wendy on a shelf; he reached towards it, and then, taking a bottle of poison from his pocket, poured the contents into the glass.

Peter Pan woke up. He remembered his promise to Wendy, and went to drink the poison. At that moment Tinker Bell rushed in crying:

"Don't drink! Don't drink!"

But her warning was useless.

"I have promised Wendy," answered Peter, and walked towards the glass with his hand outstretched.

In vain did Tinker Bell warn him; but, just as Peter was about to drink, the little Shining Light popped into the glass and drained all its deadly contents. Then it flickered and paled and drooped towards its bed, dying.

Peter knew there was only one way in which he could possibly save it.

"Do you believe in fairies? Oh, please say you believe in fairies!" he cried to all the world. And back from the world, which was so sorry for poor little Tinker Bell, came the answer:

"We believe in fairies."

So Tinker Bell revived and was saved, and she told Peter Pan how the pirates had carried off the lost boys, with Wendy and her brothers, to their ship, and of the danger in which they stood.

Peter immediately started out. He arrived at the ship just as the captain was going to flog his prisoners before making them walk the plank. Peter Pan had an alarm clock in his pocket; he took it out, and at the first sound of that *tick-tick* the captain gave a great cry of horror, thinking that the cr-r-r-rocodile was near.

During the panic, Peter stole on board ship and hid himself in the cabin where the cat-o'-nine-tails was hidden.

The clock ran down. The captain grew brave again.

"Go and get the cat-o'-nine-tails!" he ordered.

One of the ruffians went to obey. As he entered the cabin a terrible shriek resounded all over the ship. Another pirate was ordered to go and see what had happened. He, too, uttered a ghastly shriek, and did not come out.

The rest of the crew were now in a state of panic. They refused to enter the cabin; one threw himself into the sea.

Suddenly Peter Pan rushed out, sword in hand, and a terrible fight followed. Captain Hook was flung overboard, where the crocodile was waiting for him; and all the rest of the wicked pirates were killed.

Then Wendy and all the boys went home, and you can imagine how glad Mrs. Darling and Mr. Darling and Nana were to see their lost children. Mr. Darling, we must tell you, had been so repentant for his crossness that he had made Nana live indoors and dine at the table and occupy his own chair; while he himself slept in a kennel outside, and ate all his meals out of a dog's trough. Mrs. Darling had always kept the window open, hoping that the children would return; and used to play and sing "Home, Sweet Home," thinking that they might hear her and come back.

But Peter Pan, all alone in Never-Never-Land, longed for little Wendy; and Mrs. Darling allowed Wendy to go every now and then to visit Peter, and see that his house was nice and tidy. Peter Pan always refused to grow up, and Wendy never forgot the fairies.

LITTLE TINY THUMBELINE

ONCE upon a time there lived a young wife who longed to possess a little child, so she went to a fairy and said to her: "I wish very much to have a child, a little tiny child. Will you give me one, dear fairy?"

"With all my heart," replied the fairy. "Sow this barleycorn in a flowerpot, and then see what will happen."

"Thank you, thank you!" cried the woman, giving the fairy a silver coin. Then home she went, and planted the barleycorn, and immediately there shot up a large flower like a tulip, but with the petals tightly closed like a bud.

"What a lovely flower!" said she, and kissed it. The bud opened at once with a loud voice, and there, in the center of the flower, sat a little tiny girl about an inch high, scarcely bigger than her thumb. So she called her Thumbeline, and put her to bed in a walnut shell, with violet leaves for her mattress and a rose leaf for a quilt. During the day she told Thumbeline stories, and taught her to sing, as she played on the table beside her.

But one night a great, wet, ugly toad came and stole away the cradle with little Thumbeline asleep in it, and carried it off to her home in the muddy bank of the brook that flowed past the end of the garden.

"This is just the wife for my son," thought she. But when her ugly son saw her, all he could say was "Croak, croak, croak!"

"Don't make so much noise, or you'll wake her," said the old Mother Toad. "She may easily escape, for she is as light as a feather. We must take her out and place her on one of the large water-lily leaves in the middle of the brook, while I prepare our house for you both."

This they did, and when poor little Thumbeline awoke and found herself in the middle of the stream, she cried most bitterly.

As soon as old Mother Toad had decorated her home with bulrushes and yellow buttercups, she and her hideous son swam out to the leaf to fetch the cradle so as to place it in their new home before taking the little maid herself there.

Old Mother Toad bowed low in the water, and said: "Here is my son, who is going to be your husband. I will come and fetch you soon, and you will be very happy together."

Then they swam off with the cradle,

and poor, terrified Thumbeline wept bitterly. Now, some little fishes had overheard old Mother Toad, and when they saw the little maid so sad they gnawed away the stem of the leaf, and away it floated down the stream, so fast that the toad could not catch it. Thumbeline became happy again, for everything she passed was so lovely in the sunshine, and the birds on the branches sang to her as she floated by. A pretty little butterfly hovered round her, and at last settled for a moment on the leaf, for he loved her very much. She was pleased, too, and tied him to the leaf with her sash.

But presently a great ugly cockchafer came buzzing past. He caught sight of her, and snatching her off the leaf, flew up with her into a tree; but the poor butterfly could not free himself, and went floating along downstream. The cockchafer gave Thumbeline some honey to eat, and praised her beauty; but when the henchafers saw her, they said that she was just like a human being.

"How very, very ugly she is!" they all cried; and at last the cockchafer disowned her, and they all flew down with her and set her on a daisy. Then she wept because she was so ugly that the henchafers would have nothing to do with her.

All the summer Thumbeline lived alone in a wood, dining off the honey from the flowers, and drinking the dew that every morning spangled the leaves around her. But then came the cold, long winter; the flowers all died, the birds flew away, and the snow began to fall. Poor hungry Thumbeline wandered through the stubble of a cornfield hard by until she came to the hole of a field-mouse, who dwelt snugly down in the ground, having a room full of corn, and a neat kitchen and store-room.

The fairies came out from their flowers and brought Thumbeline presents

Thumbeline stood at the door and begged for food.

"Poor little thing!" said the good-natured field-mouse. "Come into my warm room and dine with me." And she soon became so fond of the tiny maid that she said: "You may dwell with me all the winter, if you will only keep my room clean and neat, and tell me stories, for I love stories dearly." And Thumbeline agreed, and was very happy in her new home.

In a few days' time the field-mouse said: "We shall have my next-door neighbor, the mole, in to visit us tomorrow; he comes to see me once a week. He is richer than I am, has large rooms in his house, and wears a beautiful black velvet coat. It would be capital if you married him; but he is blind, and cannot see you, so you must tell him your prettiest stories."

When he came, Thumbeline sang to him, and he soon fell in love with her. He invited them to walk down a long, dark passage that he had just burrowed from their house to his, lighting them with a piece of tinder.

But when they had gone a short distance they found a swallow lying stretched on the floor; the poor bird had evidently died of cold. Thumbeline felt very sorry, as she loved all the birds, but the mole kicked it with his short legs, saying:

"Here's a fine end to all its whistling! What a miserable thing it must be to be born a bird! None of my children will be birds, thank goodness!"

But Thumbeline could not sleep that night, so she got up, and wove a carpet out of hay and then went and spread it round the bird; she also covered it with some warm, soft cotton.

"Farewell, dear bird," said she; "farewell, and thank you for your beautiful song in the summer, when all the trees were green and the sun shone so warmly upon us." And she pressed her head against his big body. To her great surprise she felt something beating within it. It was the bird's heart, and he was not really dead. She quickly laid the cotton more closely round him, and he gradually revived.

He remained underground all the winter, and Thumbeline was kind to him and brought him water and food; but she never said a word either to the mole or the field-mouse.

As soon as the spring came the swallow said farewell to Thumbeline, who would not go with him, because she knew it would vex the old field-mouse if she left her.

Thumbeline was now sad indeed, for she was not allowed to go into the warm sunshine.

"This summer you must work and make your wedding clothes," said the field-mouse, for the blind, dull mole had decided to marry Thumbeline.

So the tiny maid was obliged to work hard at the distaff, and the field-mouse hired four spiders to spin and weave.

Every evening the mole came and talked about how the summer was coming to an end, and he abused the sun and pretty flowers so much that Thumbeline disliked him more and more, and said she would not marry him.

"Fiddlestick!" cried the field-mouse. "Don't be obstinate, child, or I will bite you with my white teeth."

At last the day fixed had arrived, and Thumbeline went to bid a last farewell to the beautiful sun before going to dwell with the mole deep down in the earth.

"Farewell, thou glorious sun!" she cried, as she walked a little way.

"Tweet, tweet!" And she heard a fluttering of wings, and there was the little swallow. She told him her sad fate and how she longed to be free.

"The cold winter will soon be here," said the swallow; "I shall fly far away to the warm countries. Come with me, sweet little Thumbeline, who didst save my life when I lay frozen in the dark earth."

"Yes, I will go with thee," said she; and she seated herself on the bird's back, and then the swallow soared high into the air and flew away over forest, lake, and mountain, until they reached the warm countries. There the sky seemed twice as high and twice as blue, and there grew the loveliest green and purple grapes, and citrons, and melons.

Near a calm, blue lake stood a half-ruined palace of white marble, and here the swallow had built his nest.

"This is my house," said the swallow, "but I will take you to one of the splendid flowers growing beneath us, and you shall dwell in one of them."

But what was her surprise when she saw sitting on the flower a little manikin wearing a gold crown on his head and the brightest, most delicate wings on his shoulders, scarcely any bigger than herself. He was the spirit of the flower, and in every flower there dwelt one such fairy, and he was their king.

When he saw Thumbeline he was delighted, for he had never seen so lovely a maiden. So he put his gold crown on her head and asked her to be his queen. And Thumbeline said "Yes," and then all the fairies came out from their flowers and brought her presents, and the best of all was a pair of transparent wings, which enabled her to fly from flower to flower.

"You shall no longer be called Thumbeline," said the king to her, "for it is not a pretty name, and you are so lovely. We will call you Maia."

And she dwelt with him ever after.

THE PYGMIES

THERE is an old saying that "truth is stranger than fiction." This seems to be just as true today when we read the stories of recent travelers and explorers about the strange peoples and races they find in the wilds of distant lands. One of the most wonderful recent discoveries is that of a new race of pygmies that dwell on the flanks of the great Snow Mountains in Dutch New Guinea, Africa.

Ancient writers were fond of recounting the adventures of these little people, and the folklore of Africa and Asia and Europe bases many of its strangest stories upon pygmy life. Our nursery tales of gnomes and fairies, goblins, pinkies and brownies have undoubtedly come down, generation after generation, by word of mouth, from the dim, primeval days when pygmies wandered dry shod across the land-bridge that connected India with Africa, and when the island of Sicily was part of the highway from northern Africa into Southern Europe. Although no pygmy in the wilds has ever seen pencil or paper, yet the race is immortalized in the company of Trojan and Greek, and until modern times has been regarded as equally mythical.

Homer, who lived in the ninth century B. C., began the story, comparing the arming Trojans, rushing to war, with cranes migrating to the pygmies' land:

"So when inclement winters vex the plain
With piercing frosts, or thick-descending rain,
To warmer seas the cranes embodied fly,
With noise, and order, through the midway sky,
To pygmy nations wounds and death they bring . . . ."

Battling with the storks

Aristotle, another Greek, knew full well of the existence of pygmies; Herodotus describes them as battling with the storks which came to raid their crops. These and other ancient writers got the main fact correct as to the existence of the little people; but, as in other dealings with natural history, they mingled the marvelous with the matter-of-fact. Their tales of pygmies with pygmy horses and other tiny, domesticated animals, of the tiny people having to cut down their crops with axes, of their requiring a ladder to mount into the goblet of Hercules, were, of course, as fabulous as the legend of their fashioning the spear of Odin and the world-shaking hammer of Thor. And because of this leaven of romance the whole story of pygmies was discredited until certain African travelers burst into the twilight gloom of the forests and first discovered a kingdom of real midgets.

There are two groups of pygmies now known—Negrillos and Negritos—consisting of many tribes. Some are found in the Andaman Islands, in the Bay of Bengal; half a dozen distinct tribes are in the Congo; there are the tiny Bushmen of South Africa, the Aetas of the Philippine Islands, the Samange of Malacca, the pygmy tribes in Formosa, and now, also, these little people in Dutch New Guinea.

Herodotus, the ancient Greek writer, was then not wholly mistaken in describing his pygmies as defending their crops against great birds.

The latest discoveries in Dutch New Guinea are on the side of the ancients. The Tapiros, as the newly known midgets are called, do cultivate crops. They cultivate sweet potatoes, tobacco, and sugar-cane. African pygmies of today have no crops, but they wage war upon the giant cranes which haunt the head waters of the Nile.

They knew the use of fire and, in a primitive way, iron-smelting and working. Their spear-heads are of iron, smelted and worked by themselves, and the tips are poisoned with a virus of terrible potency. They live in tiny huts in the forest—huts only 4 feet in height, bare of any suggestion of furniture, and entered by a low opening through which the tenant crawls on all fours. Spears are their only assets. These constitute the purchase price of a bride, and upon the product of the weapon they live. They attack and kill the mighty elephant; they hunt the okapi. It is a strange fact that the discovery of the Congo pygmies gave this extraordinary animal to the knowledge of the world. No white man had ever seen an okapi ten years ago, and only rumors of its existence had been heard.

At home the pygmies are feared and avoided by other natives. They inhabit the reeking, steaming forest, impenetrable to all save themselves, and pass their lives in a perpetual twilight, amid mighty trees laced and bound together with vast creepers, in and out of which little men run like rabbits.

The same habits and method of living distinguish the majority of pygmy tribes. For the most part all have like features: the dark skin, the ape-like mouth; the broad, flattened nose; the woolly, "pepper-corn" hair.

Like the tiny Shetland ponies and the diminutive Shetland sheep dogs, the pygmies make up in intelligence what they lack in inches.

But the pygmies most recently discovered—those of Dutch New Guinea—appear to be in advance of their fellows. They are husbandmen, growing their own crops. They make bows and arrows, and use them with astonishing skill, employing them against birds, rats, mice, and other small animals.

THE ARTFUL MOLE AND THE INNOCENT BLACKBIRD

"Tell us about the most wonderful escape you ever had from an enemy, will you, daddy?" said an excitement-loving little Blackbird, sitting alongside one of his brothers on a twig overhanging a cattle pond.

"Oh, let me see, let me see," mused the sable old bird with the orange bill. "I think the most curious adventure I ever had, and certainly the narrowest escape, happened to me when I was a young fellow, just learning to sing.

"Blackbirds are all early risers, and I used to leave my cozy roosting perch under a tuft of ivy at the first peep of day regularly every morning, in order to listen to my father, who was a capital singer, and such a cunning old bird, too!

"One day he said to me, 'Jack, do you know an easy way to catch worms?'

" 'No, father,' I answered.

" 'Well, I'll tell you, then, lad. If ever you see a mole at work throwing up a hillock of earth, just hop quietly along to the place, and ninety-nine fat caterpillars to a lean daddy longlegs, you'll observe a terrified worm or two hurrying to the surface of the ground in order to escape from their enemy below. Once they have left their holes you can pick them up and swallow them as easily as ever you please, for it's what men call a case of "out of the frying pan into the fire" so far as the worms are concerned.'

" 'Thank you very much indeed. That is a pretty wrinkle, and no mistake, dad,' said I with glee.

" 'Yes, Jack,' replied my father, 'but it's just like all pretty things—it needs to be approached with care, as the puppy dog said when he tried to play with the wasp. You must be very careful the mole does not catch hold of you, for he is an awful cannibal, and the monster that will eat his own grandmother would not hesitate to breakfast off you.'

"Being dragged underground alive and devoured in a mole's dark tunnel struck me at the time as being rather an unpleasant way of ending one's career; but warnings have a trick of slipping from the minds of over-confident young people, and I had forgotten the dangerous side of my father's information in less than a week.

"I was standing on the topmost branch of a dead tree early one morning, listening intently to my worthy parent's top notes, when I observed a tiny clod of earth roll off the top of a newly made mole hill. Now's my chance, thought I, never dreaming of the great surprise in store for me.

Keeping my eye steadily fixed on the spot, I saw the mole give another heave, and out came a great red worm, helter-skelter. I was on him like a shot, and thought I had never in all my life tasted such a delicious morsel.

"I waited about for some time, feeling sure that other worms would come to the surface; but in vain, the mole had ceased to work.

"By-and-by, a monster just showed his great pink head on the crown of the newly-made hillock, and I grew so excited I could hardly stand still.

"I waited and waited, and as the mole did not burrow any more the worm also waited and waited. I naturally supposed that as there was no enemy at work beneath him he did not see the fun of coming out to make a meal for me, so I decided to pounce upon him and drag as much of his body out as I could.

"I made a wild dash at him, and never got such a fright in all my life."

"Whatever happened, daddy?" asked both the young Blackbirds excitedly.

"Well, what I supposed to be the head of a worm proved to be the nose of the artful old mole. Whether he had stuck it out in order to get a breath of fresh air, or as a deliberate bait for me, will never be known; but directly I seized it he seized me, and it is a wonder I'm alive to tell the tale.

"The brute instantly tried to drag me underground, but being a strong young bird and my bill hard and slippery he lost his hold, and I made my wings go faster than they ever flapped before or since.

"It was a full week before I dared look at a worm again.

"Take my advice, children, and examine early worms well, especially when they thrust their heads out of mole hills. Man-made proverbs need applying with caution, and I should tie on behind 'It is the early bird that catches the worm,' but 'All is not gold that glitters.' "

THE ARCHER FISH—A FINNY SPORTSMAN

MANY tall stories have been discredited since scientists began sternly to demand proof of alleged facts, but nevertheless it has been recently established that there are fish that share with man the sporting instinct. Of these finny sportsmen the Archer is king.

"We have," said Sir Charles Bell, "a curious instance of the precision of the eye and of the adaptation of muscular action, in the beaked chætodon, a fish which inhabits the Indian rivers and lives on the smaller aquatic flies. When it observes a fly alighted on a twig, or flying over it—for it can shoot them on the wing—it darts a drop of water with so steady an aim as to bring the fly down into the water, when it falls an easy prey. It will hit a fly at the distance of from three to six feet. Another fish, of the same order, the Zeus, has the power of forming its mouth into a tube and squirting at flies, so as to encumber their wings and bring them to the surface of the water. In these instances a difficulty will readily occur to the reader. How does the fish judge of position, since the rays of light are refracted at the surface of the water? Does instinct enable it to do this, or is it by experience?"

Nearly a century ago travelers reported having seen specimens of the Jaculator fish in Java. They were exhibited by a native chief, who kept them in a pond, in the middle of which was placed a short branch. For the amusement of his visitors the chief instructed attendants to place living beetles on it.

Expert gunners

"When the slaves had placed the beetles, the fish came out of their holes and swam around the pond," says one account. "One of them came to the surface of the water, resting there, and, after steadily fixing its eyes for some time on a beetle, it discharged from its mouth a small quantity of water with such force and precision of aim as to strike it off the twig into the water, and in an instant swallowed it. After this another fish came and performed a similar feat, and so the sport continued until they had secured all the beetles. If a fish failed in bringing down its prey at the first shot, it swam around the pond till it came opposite the same object, and fired again. In one instance a fish returned three times to the attack before it secured its prey, but in general the fish seemed very expert gunners, bringing down the beetle at the first shot."

When the Jaculator fish intends to catch a fly or any other insect which it sees at a distance, it approaches very slowly and cautiously, and goes as much as possible perpendicularly under the object; then, the body being put in an oblique position, and the mouth and eyes being near the surface of the water, the Jaculator stays a moment quite immovable, having its eyes directly fixed on the insect, and then begins to shoot, without ever showing its mouth above the surface of the water, out of which the single drop, shot at the object, seems to rise. With the closest attention, one can never see any part of the mouth out of the water, though the Jaculator fish shoots a great many drops one after another without leaving its place and fixed situation.

They frequently swim backwards as well as forwards, says Zolotnitsky, a Russian savant. This habit of swimming backwards is very curious and quite customary; indeed, they often swim in this manner for several minutes at a time. They reconnoiter a possible prey, and back from it until they secure a good position for observation and attack.

The action of the eyes deserves special notice. They can be moved in almost every direction—to the left, to the right, upwards, and backwards—backwards so that the fish can see everything that goes on behind. Their vision is also very penetrating; they can see small objects at a great distance, and drench them with astonishing correctness of aim. But the eyes cannot be turned downwards, and, consequently, when the fish would see what is below, it plunges forward, head foremost. It rarely sees what is at the bottom, and although worms may be there in abundance, it finds them only when hunger impels it to search for them there. And it is not alone the movement of the eyes which engages attention; instead of the expressionless stare which is characteristic of fishes generally, the Archer's eyes sparkle with intelligence. Especially when the fish becomes sick or dying is the expression manifested; then it looks at you as if it would implore your attention and would like to speak. Apparently there are few limits to the ingenuity of the Archer fish. This finny tribe certainly does not seem to be less greedy than its fellows. It appears that the less expert gunners, finding that their clumsy efforts merely resulted in driving insects away from the aquarium, desisted in favor of the adepts of the family. When the latter exercised their skill, the other fish waited in readiness to snap up the spoil before the successful sportsman could secure it.

LITTLE PLAYS AT HOME

HINTS: 1. Stage Properties are those articles which are used in a play either for scenery or for dress. One child should be appointed to look after these properties. He must see that they are in their proper places before the curtain rises and at hand as the scene goes on.

2. Each child is responsible for his own personal properties, that is to say, the articles of dress, swords, armor, etc., belonging to his part.

3. In setting or arranging the scenery, the Right is on the right hand and the Left on the left hand as you stand facing the stage, with your back to the audience.

4. The Prompter should stand, out of sight of the audience, at the side of the stage, book in hand, ready to give the missing word or sentence, should any one forget his part.

SCENE FROM ROBIN HOOD

CHARACTERS: King Richard Cœur de Lion; Three Nobles, attendants on him; Robin Hood; Little John; Much; Allan-a-dale; Friar Tuck; Robin Hood's Merry Men; Maid Marian; Lady Christabel.

STAGE PROPERTIES: Green cloth for floor, bank, bushes, mugs, platters, jug for wine, dishes, dinner things, silver and crystal bowl. For the bank, a biggish box banked up with cushions. Cover it with cloth and ivy. Bowl in bright new tin basin, and crystal fruit dish. For dinner dishes, have as many covered dishes as possible, plates of fruit, bread, etc. Sham fowls, meat, etc., can be bought, but these are not necessary with covered dishes. A big soup tureen looks well. This scene can be acted out of doors.

SCENE: An open space in Sherwood Forest. To the *Right* and *Left*, trees or greenery; at the back a bank. When the curtain rises King Richard is discovered standing in center; near him the three Nobles. They are all dressed in monks' cloaks, with hoods well drawn over their faces.

The King [*looking round him*]: Well! I hope we shall see the fellow this time.

First Noble: There is not much fear of that: Robin Hood finds out monks as quickly as bees do honey. We shall not have long to wait, your Majesty.

The King [*softly, putting finger on lip*]: Hush! He may be listening now, and if he guesses who I am our game is spoilt. Remember I am only an abbot for today. [*louder*] The fellow is well off here: sunshine and green trees, flowers and the song of the birds for company—who could want more?

Second Noble [*speaking quickly*]: I saw something moving down there . . . through the trees . . . take care, my Lord!

The King [*still loudly*]: For my part, I have no fear of the man. He would not dare rob *me*.

Robin Hood [*stepping from behind a tree, all in green, with bow and arrow,* *and horn*]: You speak too soon, my lord abbot—for an abbot I take you to be by your dress and manner. Robin Hood dare rob whom he will, when he has need of money, so you had better come with me peacefully. I have a hundred men within call, and I am not over fond of monks.

The King: If we are monks, we are also messengers from the King. If you are the famous Robin Hood . . .

Robin Hood: I am Robin Hood.

The King: Then his Majesty sent us to say that he would see you. As a sign he sends you this ring [*showing ring on his hand*].

Robin Hood [*after looking at it, taking off his hat*]: It is truly the King's ring. God bless him: God bless all those that love him: cursed be all those who hate him and rebel against him.

The King: Then you curse yourself, for you are a traitor and an outlaw.

Robin Hood [*fiercely*]: I am an outlaw may be, through no fault of mine, but I am no traitor, and if you were not the messenger of the King you would pay dearly for that lie. I have never yet hurt any true and honest man: I have robbed only from the tyrant rich, never from the poor: I fight against monks and abbots, and take their money from them when I can, because they steal from the poor. They ought to live good lives and show others a good example, but they do not. They live wickedly, and should be punished. If they had ruled England well when King Richard was away, we should not have to live in the woods as we do now. [*Kindly.*] But do not fear, you are the King's messengers, and therefore welcome to all that we have. Stay here, and sup with us; we will make you comfortable as we know how.

Third Noble: They wait for us at Nottingham, my lord.

The King: Let them wait: the King wishes to know as much as possible about this man. If we do not fare well, it will matter not for once.

Robin Hood: You shall eat of our best, Sir Abbot, though if you came not from the King I doubt if you would be so well treated.

[*Blows his horn. Enter quickly* Little John, Much, Allan-a-dale, *and others: they are all dressed in green.*]

Little John: What news, master?

Robin Hood: None that will fill our pockets, my little John. These good monks are messengers from the King, and therefore safe from us. Much!

Much: Yes, master!

Robin Hood: . . . Tell the cook that we shall dine here, and that we must have as fine a feast as if the King himself were among us.

Much: Yes, master! [*Goes out by Left quickly.*]

Robin Hood: Allan - a - dale, go bring me here Maid Marian, and your sweet Christabel; tell them we have need of their help to entertain our noble company.

Allan-a-dale: I go right gladly, master. [*Exit by Left.*]

Robin Hood [*to the others*]: Now, men, help bring the things and do your parts with a right good will. Let us show these gentlemen what we poor foresters can do.

All: Ay, that we will, master!

[*Exit all foresters, save* Little John. *They all drop on one knee before* Robin *as they pass out.*]

The King: Upon my word, Sir Outlaw, you are master of a gallant company. It is a pity that you should live as you do—shooting down the King's deer, robbing his faithful bishops and knights.

Robin Hood: I cannot starve my men, Sir Abbot, and were Richard himself here I think he would scarcely grudge these fine men their food.

The King: Perchance not, but it is against the law.

Robin Hood: I know that well, Sir Abbot, but what else can we do? Our homes have been burned down by the Norman nobles, our lands have been stolen, our money taken, and they would have made us their slaves. Rather than that, we have chosen to live here in the merry greenwood. We are Englishmen, Sir Monk, and we would be free.

The King: Well spoken! Well defended, Robin!

[*Enter by Left* Allan-a-dale, *with* Maid Marian, Lady Christabel, *and* Friar Tuck.]

Maid Marian [*curtsying*]: Welcome to Sherwood Forest, Sir Abbot!

The King: Who is this fair lady?

Friar Tuck [*pushing forward*]: Have you never heard of Maid Marian, Robin Hood's sweet bride, and Queen of our merry greenwood? She comes of noble blood, but rather than be parted from her Robin she fled to the forest all in knightly array. There she again met our master, and the two young things fell to fighting together, neither knowing the other; presently Robin spoke and the lady discovered herself, and the end of it all was that I married them myself. Ah, it was a merry wedding!

The King: Who is this jolly monk?

Friar Tuck: Friar Tuck, at your service, my lord abbot, and a very busy man. Look at these two [*pointing to* Allan-a-dale *and the* Lady Christabel]. I married them under the old bishop's nose: I cried them seven times in the church lest there should be some mistake. They are a couple to be proud of. They . . .

Robin Hood: Friar Tuck, Friar Tuck, your tongue clacks too loudly.

Friar Tuck: Not so, master, not so; you would be badly off without its clacking, I'll warrant. Who would marry you? Who would bless you? Who would say grace at meat in the Latin tongue? Who would . . .

[Little John *takes him by the arm and leads him away.*]

Robin Hood [*laughing*]: He is a merry soul!

[*Enter a Page (or Pages) with silver or crystal bowl and towel. He kneels before the* King, *holding the bowl while he washes his hands, then goes to the Nobles. Men in green come hurrying in with mugs, platters, dishes, food, etc., which they set on the grass.* Little John *orders them here and there: the* King *and Nobles talk to* Maid Marian *and* Christabel. *Presently* Robin Hood *blows his horn: all the men stand round.*]

Robin Hood: Fill up the mugs, men, to the very brim: before we eat we will drink the King's health.

[*They fill up mugs, giving them also to the* King *and Nobles.*]

All *drinking* [*led by* Robin Hood]: God save the King!

The King: If I could get you pardon from the King, Robin, would you be willing to leave this wild life in the woods and serve him forever? He has need of loyal and true men like you.

Robin Hood: With all my heart!

The King [*to the men*]: Men, would you be willing to serve the King of England, Richard Cœur de Lion?

All [*flinging their caps into the air*]: With all our hearts! . . . God save the King!

Robin Hood: You see, Sir Abbot, we are all loyal people here.

The King [*huskily*]: So I see!

Robin Hood: If you would but ask the King to forgive me, I think I could once more respect monks. A bishop was the first cause of all our misfortunes, and because of that I have hated them all, but from this day I shall respect them.

THE KING [*flinging back the monk's hood*]: There is no need to ask the King for pardon. I am the King, your sovereign, and I forgive you gladly, Robin.

ROBIN HOOD [*falling on his knees*]: O Sire!

THE KING: Stand up, stand up, my friend: I doubt if in all England, I have more faithful followers than you and your men.

LITTLE JOHN: The King! God save us! . . . The King! !

MUCH *and Others:* The King! The King! [*They all kneel.*]

THE KING: Rise, all! I am King Richard of England: are you ready to follow me as your master, and be my men?

ALL: We are, we are!

THE KING [*gaily*]: Then let us sup, and after we will to Nottingham, and surprise them.

ALL: Long live the King! Three cheers for Cœur de Lion! And three for Robin Hood!

[*The* KING *gives his hand to* MAID MARIAN, ROBIN HOOD *to* CHRISTABEL. *As they all seat themselves round the feast the* CURTAIN *falls.*]

SCENE FROM UNCLE TOM'S CABIN

CHARACTERS: MISS OPHELIA, EVA, TOPSY.

STAGE PROPERTIES: Bed or sofa arranged as bed, and any other bedroom furniture. Ribbon, gloves, dressing table, etc.

NOTE.—In this scene there is no need to keep strictly to stage directions. Set it as seems most convenient.

SCENE: MISS OPHELIA'S bedroom: Door to the *Left;* at the back in center a bed, or couch arranged as bed, standing out from the wall; to the *Right* side of the bed, a dressing-table: on it, besides the usual looking-glass, etc., a bright red ribbon and a pair of white gloves. Chair to *Right* near front of stage. Book-case, pictures, and other furniture, according to convenience. When the curtain rises, MISS OPHELIA is discovered sitting on chair to *Right;* opposite to her stands TOPSY, hands folded, eyes fixed on the ground.

MISS OPHELIA: Now, Topsy, you are clean and tidy at last, I hope?

TOPSY: Laws, yes, Miss Feely! There's not a speck o' dirt left on me.

MISS OPHELIA: That is better: I hope you will always keep clean and tidy in the future. There is nothing I dislike so much as dirt.

TOPSY [*rolling her eyes and making a face*]: Yes, missis.

MISS OPHELIA: Now I have a few questions to ask you before we set to work. How old are you, Topsy?

TOPSY [*grinning*]: Dunno, missis.

MISS OPHELIA: Don't know how old you are! Did nobody ever tell you? Who was your mother then, child?

TOPSY [*with another grin*]: Never had none.

MISS OPHELIA: Never had any mother! What do you mean? Where were you born?

TOPSY: Never was born.

MISS OPHELIA [*sternly*]: You mustn't answer me like that, child. I am not playing with you. Tell me where you were born and who were your father and mother.

TOPSY [*emphatically*]: Never was born, never had no father, nor mother, nor nothin'!

MISS OPHELIA: Topsy, how can you say such things! How long have you lived with your master and mistress?

TOPSY: Dunno, missis.

MISS OPHELIA: Is it a year, or more, or less? Try to answer properly this time.

TOPSY: Dunno, missis.

MISS OPHELIA: Worse and worse!

Do you know anything at all, I wonder! Have you ever heard of God, Topsy? [Topsy *shakes her head.*] Do you know who made you?

Topsy [*laughing*]: Nobody as I knows on: 'spect I grow'd. Don't think nobody ever made me.

Miss Ophelia [*shocked*]: Terrible! whatever shall I do with a child like this! Do you know how to sew, Topsy?

Topsy: No, missis.

Miss Ophelia: What can you do? What did you do for your master and mistress?

Topsy: Fetch water, wash dishes, and clean knives and wait on folks.

Miss Ophelia [*going to left side of bed*]: Well now, Topsy, I'm going to show you just how my bed is to be made. I am very particular about my bed. You must learn exactly how to do it. Come to the other side and watch me well.

Topsy [*going to right side*]: Yes, ma'am.

Miss Ophelia: Now, Topsy, look here. This is the hem of the sheet, This is the right side of the sheet. This the wrong. Will you remember?

Topsy [*with a big sigh*]: Yes, ma'am.

Miss Ophelia: Well now, the undersheet you must bring over—like this—and tuck it right down under the mattress, nice and smooth—like this. Do you see?

Topsy [*with a bigger sigh*]: Yes, ma'am.

Miss Ophelia: But the upper sheet must be brought down and tucked under, firm and smooth at the foot—like this—the narrow hem at the foot.

Topsy [*snatching the gloves and the ribbon off the dressing-table, as* Miss Ophelia *bends over the bed*]: Yes, ma'am. [*Slips them into her sleeve.*]

Miss Ophelia [*pulling off the clothes again*]: Now, Topsy, let me see if you can do it. [Topsy *quickly and neatly makes the bed again.*]

Miss Ophelia [*watching her*]: Very good . . . very good indeed, Topsy! We shall make something of you yet.

Topsy [*tucking in the sheet*]: Yes, missis. [*As she does so the ribbon falls from her sleeve.*]

Miss Ophelia [*picking it up*]: What is this? You naughty wicked child, you have been stealing!

Topsy [*very surprised*]: Why! That's Miss Feely's ribbon, an't it? How could it a' got into my sleeve?

Miss Ophelia: Topsy, you naughty girl, don't tell me a lie. You stole that ribbon.

Topsy: Missis, I declare I didn't. Never seed it till dis blessed minnit.

Miss Ophelia: Topsy, don't you know it is wicked to tell lies?

Topsy: I never tell no lies, Miss Feely. It's jist the truth I've been tellin' now. It an't nothin' else.

Miss Ophelia: Topsy, I shall have to whip you, if you tell lies so.

Topsy [*beginning to cry*]: Laws, missis, if you whips all day couldn't say no other way. I never seed that ribbon. It must a' caught in my sleeve. Miss Feely must a' left it on the bed, and it got caught in the clothes, and so got in my sleeve.

Miss Ophelia [*angrily shaking her*]: Topsy, how dare you! Don't you tell me that again. [*The gloves fall to the floor.*]

Miss Ophelia [*holding them up*]: There! Will you tell me you didn't steal the ribbon?

Topsy [*still crying loudly*]: O missis, missis, I'se so sorry! I won't never do it again, I won't.

Miss Ophelia: Stop crying then, and tell me if you have taken anything else since you have been in the house. If you tell me truthfully, I won't whip you.

Topsy: Laws, missis, I took Miss Eva's red thing she wears on her neck.

Miss Ophelia: You did, you

naughty child! Go and bring it me this minute.

TOPSY: Laws, missis, I can't—they's burnt up.

MISS OPHELIA: Burnt up? What a story! Go and get them or I shall whip you.

TOPSY [*groaning and crying*]: I can't, I can't, Miss Feely! They's burnt up, they is.

MISS OPHELIA: What did you burn them up for?

TOPSY [*rocking to and fro*]: 'Cause I'se wicked, I is. I'se mighty wicked. I can't help it.

[*Enter* EVA *wearing red necklace.*]

MISS OPHELIA: Why, Eva, where did you get your red necklace?

EVA: Get it? Why, I have had it on all day, and what is funny, aunty, I had it on all night. I forgot to take it off when I went to bed.

MISS OPHELIA [*lifting her hands in despair*]: Whatever shall I do with her! What in the world made you tell me that you took the necklace, Topsy?

TOPSY [*wiping her eyes*]: Missis said I must 'fess. I couldn't think of nothin' else to 'fess.

MISS OPHELIA: But of course I didn't want you to confess things you didn't do; that is telling a lie just as much as the other.

TOPSY [*very surprised*]: Laws now, is it?

MISS OPHELIA: Topsy, what makes you behave so badly?

TOPSY [*grinning*]: Dunno, missis; 'spects it's my wicked heart.

MISS OPHELIA: What shall I do with you? I'm sure I don't know; this is terrible.

TOPSY: Laws, missis, you must whip me. I an't used to workin' unless I gets whipped, but I dunno that it helps much neither.

MISS OPHELIA [*going to door*]: I never saw such a child! Topsy, if you do not try to be more honest, and better in every way, I shall have to speak to your master. [*Exit.*]

EVA: What makes you so naughty, Topsy? Why don't you try to be good? [*Taking her hand.*] Don't you love anybody, Topsy?

TOPSY [*blinking her eyes*]: Dunno nothin' 'bout love. I love candy, that's all.

EVA: But you love your father and mother?

TOPSY: Never had none: I telled ye that before, Miss Eva.

EVA [*sadly*]: Oh, I forgot: but hadn't you any brother or sister, . .

TOPSY [*interrupting*]: No, none on 'em. Never had nothin' nor nobody.

EVA: But, Topsy, if you would only try to be good, you might . . .

TOPSY [*interrupting*]: Couldn't never be nothin' but a nigger, if I was ever so good. If I could come white, I'd try then.

EVA: But people can love you, if you are black, Topsy. Miss Ophelia would love you if you were good.

TOPSY [*laughing*]: Would she though?

EVA: Don't you think so?

TOPSY: She can't bear me, 'cause I'm a nigger. She'd as soon have a toad touch her. There can't nobody love niggers, and niggers can't do nothin'. I don't care. [*Whistles or hums, and tosses her head.*]

EVA [*laying her hand on* TOPSY'S *shoulder*]: O Topsy, I will love you: I love you now, because you haven't any mother or father or friends. And it makes me sorry to have you so naughty. I wish you would try to be good, Topsy. Won't you?

[TOPSY *suddenly sits down on the floor and hides her face in her apron.*]

EVA [*stroking her head*]: Poor Topsy!

TOPSY: O Miss Eva, dear Miss Eva, I will try . . . indeed I will. I never did care nothin' about it before.

CURTAIN.

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THE HUMAN INTEREST LIBRARY

VISUALIZED KNOWLEDGE

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VOLUME II.

CHICAGO

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DESCRIPTION OF CONTENTS

VOLUME TWO

No study is more fascinating than that of the great globe on which we live. This book deals with the great truths of the forces of nature—physics, geology and astronomy—not as dry facts, but in a charming way which captivates the imagination. It tells us how the earth was born from the primeval chaos, how under the influence of cosmic laws, here fully described, it took form and slowly cooling and shrinking through the ages, became the solid sphere upon whose crust we live; and then, taking a wider flight, it tells us all that is known of the starry heavens.

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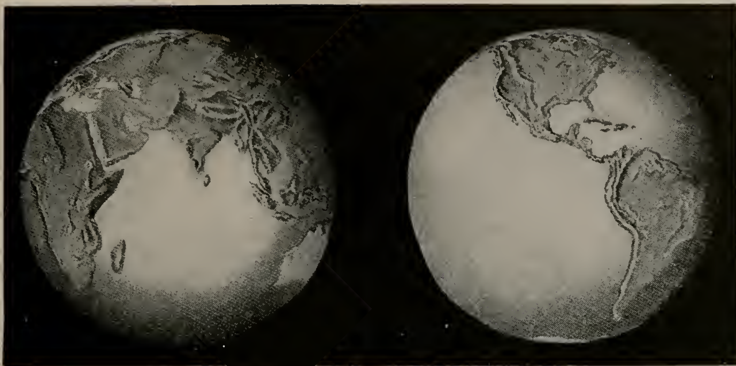
Book of Earth and Sky

THE GREAT BALL UPON WHICH WE LIVE
THE SUN AND ITS FAMILY
HOW THE EARTH WAS MADE
THE EARTH AS IT IS TODAY
THE EARTH'S CHANGING FACE
WORLDS IN THE SKIES
THE MOON, THE LAMP OF NIGHT
THE SUN'S GIFT TO THE EARTH
STARS AND CONSTELLATIONS
AIR, WATER AND FIRE

PROCESSION OF THE WORLDS IN THE SKIES

The earth is not the only world; it is only a fragment of the great Universe—the name we give to all created things. In the picture the earth looks the biggest of all the globes; but that is only because it is the nearest to us. Round the sun are many other worlds and millions of stars. The great world balls travel, always spinning, round the sun. This picture helps us to understand what a mighty universe we live in. Nobody has ever seen the universe like this because nobody can get outside it to look; and even if we could it is so vast that nobody could possibly see it all. Through a telescope we can see a little bit of the world nearest our earth; but the majesty and wonder of the universe is something that no man can fully understand.



The World is round like a ball, and this is the side of the ball called the Old World, the part of the World that was known before Christopher Columbus found America.

This is the other side of the ball, the New World, called America, which the men living in the Old World did not know until Columbus found it, four hundred years ago.

THE GREAT BALL UPON WHICH WE LIVE

THE earth on which we live is so big that we cannot possibly see it all at the same time. It has come to be what it is through millions and millions of years. Yet the earth is only one of many, many worlds, some of them much greater than the earth, all of them moving through space like a ball when it is thrown in the air. What do we know of all these worlds? How were they made? Is every star a sun like ours, and are there little children playing on balls, like the earth, that circle round the stars? How does the sun give us life and warmth? All these questions we ask as we think of the great universe in which we live, and we come to know more and more about the world as time goes on.

THE MEN WHO THOUGHT THE EARTH WAS FLAT

The first men who tried to understand the earth naturally thought that there were two or three great facts which he could start with, about which there was no doubt at all. To begin with, it seemed quite plain that, though there were hills and valleys, ups and downs, yet, on the whole, the earth was flat. The hills and the valleys seemed to be mere ups and downs, like the ups and downs on a bad road. However far you walk your head is still upright, at the top of you, and your feet are still beneath you. You will never come to an edge and fall off. Walking on the earth, or even going in a train, is not at all like walking on a ball, as people do at the circus.

Well, then, men thought that here was something plain. First of all, there was this great stretched-out earth, giving us a certain level upon which we live, and stretching out in all directions. Then men began to think of everything else in the whole world as either at that level or else above that level like the sky, or else below that level. It was not possible to get very far down below because of the difficulty of digging; but still, just as there was an above, so men knew that, of course, there must be a below.

GREAT MYSTERY OF THE UNDER WORLD

In some parts of the world it was possible, men thought, to get hints of the lower regions, and men came to learn that the earth below was hot and on fire. How did they find this out? Here and there upon the surface of the earth there are great holes, usually found at the tops of mountains. These mountains have a special name which we must learn; they are called volcanoes, and the holes are called craters. Sometimes a volcano becomes excited, and all sorts of things come up from below and are shot up into the air through the hole at the top. Now, these things that come up are all terribly hot, and with them comes a great deal of black smoke. So it seemed probable that what men called the under world—that is to say, the part below the level of the earth—was a very hot place, probably with fire always burning in it.

Another idea was that the earth was quite still and at rest. We do not feel the earth moving under our feet; we cannot imagine that it moves. If we look "up" to the stars and watch them carefully from day to day and from night to night, they seem to come up from the edge of the earth, in a direction which we call the East. Then they seem to travel across the sky, and then to dip down at the other edge of the earth, which we call the West.

WHAT MEN USED TO THINK ABOUT THE SUN

We can easily see the sun doing this, as it seems to do it every day. At some time in the morning we see it in the East; it travels across the sky, and then it passes from our sight in the West. It used to be thought that the great fire of the sun was put out every night in the water in the West, and that then, in some mysterious way, it passed through the under world, and was set blazing again, and turned up next morning in the East to begin its journey afresh. Whatever happened to the sun at night, at any rate there seemed to be no doubt that it did what we think we see it do—rise in the morning, move across the sky, and set on the other side from where we first saw it rise. The notion that the earth itself moved seemed to be such nonsense that everybody laughed at it.

But at last there came the notion that, in spite of what we think, the earth is not flat! Some bold men actually declared that the earth was nothing else than a big ball, and that we lived on the outside of it. Many people laughed at such an idea. "If it is a big ball," they said, "we should be able to go right round it and come back to where we started from." Now, in those days the only part of the earth that men knew at all was scarcely more than a spot on its surface, and beyond this they knew nothing. So this idea of traveling boldly out in one direction and going on and on until you came back to the place you started from seemed really too absurd.

COULD A MAN TUMBLE OFF THE EARTH?

Then again, people argued that there could not possibly be other people on the under side of this big ball, for if they were they would fall off, and, indeed, if it were a ball, anyone starting at the top of it, and walking too far in one direction, would soon find himself beginning to slip—just as a doll might slip off an orange—until at last he would tumble off altogether, and that would be the end of him. It seemed a great puzzle, or, rather, it seemed not a puzzle at all; it simply seemed that the people who said the earth was a ball were talking nonsense. But these people would not stop talking, and they went on with one argument after another so strongly that at last people believed that what they said was true.

HOW WE KNOW THE EARTH IS ROUND

One of their best arguments was that if you watch a ship as it sails out to sea from the harbor, it does not behave as it should behave if the sea were flat. Suppose the sea were like a flat, ploughed field. You could watch the ship go up and down and on and on, looking smaller and smaller, until at last it became just a speck, and then disappeared out of sight. But that is not at all what happens when a ship sails out to sea. If we watch it closely, we find that it begins to disappear in a particular way. The hull—that is, the bottom—of the ship disappears first, and then the ship seems to sink lower and lower, until we can see only the tops of the masts, and then only the top of the highest

HOW WE KNOW THE EARTH IS ROUND

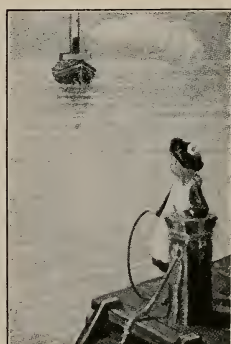
The earth is not flat like a table, but round like an orange. We know this by the way a ship comes into sight at sea. At first we see only smoke.

Then we see the top of the mast, as if the ship were climbing up the side of a hill.

Then the front appears, and we see the vessel rising higher and higher.

If the earth were flat we should see the whole of the ship at once, not the front of it first and the rest of it bit by bit.

But we do not see it that way. We see the ship rising as if it were sailing up the other side of a ball.



At last the ship is over the circle, sailing clear on the top of the ball.

mast, and then nothing at all. When it has quite gone, the ship is really near enough for us to see quite well, but it is hidden by something—something which first hides the lowest part, and then hides it all.

HOW THE SHIP COMES INTO SIGHT AT SEA

Then, supposing the ship comes back, what do we see? Is it, first of all, a sort of dim shape, which gradually becomes clearer and clearer, like a man meeting us in a street in a fog? Not at all. The ship seems to rise up from somewhere, and, as it rises, comes nearer and nearer, so that we see the tops of the masts first and the hull last.

THE FIRST MEN WHO TRIED TO SAIL AROUND THE GREAT EARTH-BALL

"Very well, then," said some bold sailors. "Very well, then; if the earth is really a ball, and if there is water enough, we shall sail around it. We shall start out from the edge of the land with our best boats and a big supply of food, and we shall go straight on and on and on, though we see nothing but water in front of us; and if you are right, and if we sail long enough and our food does not run short, we shall go right round the ball and turn up again at the place we left"—not at the same edge of the land, but at the opposite edge.

And that is what these sailors tried to do. They went out in their best and biggest boats; they turned their boats straight ahead, and waved their hands to the crying friends who thought they would never see them again. The country called Spain, which was at that time one of the most famous countries in the world, was their starting place. On they went, and we may imagine how often those sailors, who could not believe this story about the earth being round, wanted to turn back and get home again. Every day they felt they were sailing farther from their homes, and what way back could there be except the way they had come?

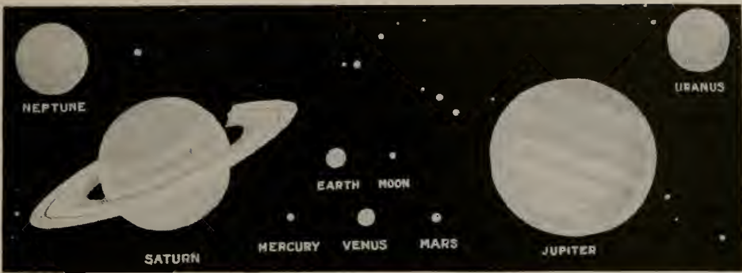
But there was to be no turning back. Each day their leaders gazed ahead looking for land—land that had never been seen, but which they hoped to be the other side of the land from which they had started. And once they nearly found what they were looking for.

It was not a great stretch of land that they saw, only some small islands, but that was quite enough, they thought. Where there were islands, they said, there would surely be land beyond them.

HOW MEN FOUND THAT THE EARTH WAS A GREAT BALL

Now, in those days, people who lived in Spain, and in that part of the world, used to call the land which lay farthest east from them the Indies. So when the sailors came across these islands, they thought that, by going round the other way, they had reached some of those same Indies which they had visited before by traveling east, and they called these islands to which they first came the West Indies, and the Indies they had left behind them they called the East Indies. Little did those bold sailors guess that instead of going all the way round they had gone only a quarter of the way.

Soon there followed other sailors, equally brave, and at last they succeeded in sailing right round the earth. That was the end of the notion that the earth was flat. These voyages discovered for us what we still call the New World, and they have been of great importance to the lives of all of us. But their greatest importance was really to prove forever that this wonderful earth is nothing else than a great ball.



We know the earth spins through space like a ball, spinning round once in a day, and traveling round the sun once in a year. But the earth was not always a great ball. Once it was a great cloud, made of the stuff of which the earth is made, and of which our bodies are made. The cloud was moving, spinning round until it came together, shrinking into the shape of a globe, and at last becoming solid. Spinning in space at the same time were other great clouds. We call them planets, which means wanderers, because they wander through the sky. They are the sun's family. One is so near to the sun that it goes round it in 88 days; one is so far away that it has only been round the sun 12 times since Jesus Christ was born. All round these planets are other worlds called moons, and millions of strange and wonderful things which go through the universe spinning.

THE SUN AND ITS FAMILY

NOW we must take up the story of the earth from the beginning. As we know that the earth is not in the middle of the world, but that it goes round the sun, we must be very sure to find out all that we can as to what the sun is, and why it makes the earth go round it. We could not live without the sun, and we cannot know too much about it. Where, then, have the sun and the earth come from, and what were they like at first?

We have seen that, as the earth spins round itself, it moves round the sun, and so we know that, so to speak, the sun is a neighbor of ours. Now we must find out whether we have any other near neighbors, and we find that we have. There is, for instance, the wonderful moon, the story of which is part of the story of the earth. But also we see in the sky a number of bright objects that look like stars, but which, for several reasons, we know are different from the stars, that we also see when we look upwards. These bright objects are not stars because, for one thing, they move about the sky, while the real stars seem to be fixed, and for ages past have been called the "fixed stars." Since they are always seen to be moving, the men of long ago called them the wanderers; but, of course, those men did not speak English, but Greek, and we now use the Greek word when we speak of them. They are called planets, which just means wanderers.

Now, of course, when we talk of wandering we think of a movement that is haphazard and does not quite know where it is going. That is not true of the planets, even though we call them wanderers. We know now that these planets all move round the sun just as the earth moves round the sun, and in just as orderly a way. That is why we may talk of the sun and its family. We must think of the sun as a great light and furnace in the center of the great world.

Around it there travel, from one year's end to another, a wonderful family of planets. One of these is the earth. It is not the biggest, nor the smallest, nor the nearest to the sun, nor the farthest from it. They all go round the sun in the same direction—they go the same way; but, of course, if a planet is farther away from the sun than the earth is, it will have much farther to go before it can get right round the sun and come back again to the same place. This takes a very much longer time then, and so "from one year's end to another" would mean something very different on that planet from what it means to us. Our earth may go round the sun more than a hundred times while one of these other planets that is much farther away from the sun goes round only once.

But all that does not matter at present. The great fact is that our earth, which is so important for us, is really just one of several planets that go round the sun. It is our sun and their sun. Now, the Latin word for the sun is *Sol*, and so this great system, made up of *Sol*—the sun—and all the planets is called the solar system. Plainly, then, we shall not be able to tell the story of the earth unless we know the story of the solar system, for the earth is part of the solar system.

Time when there was neither earth nor sun

You will remember that men used to think that the earth was flat and still, with the sky above it, and the fiery under-world below it. How different that is from what we know now—that the earth is a ball, one of a number of balls that are always flying round the sun!

Now at last we can begin at the beginning of the story of the earth. We must go back to a time when there was no earth at all, when there was no sun at all, and no planets at all.

There was only in those far-away times—we cannot say those far-away days, for there could be no days when there was no sun or earth—there was only in those far-away times a great cloud of atoms, so much bigger than any cloud you ever saw, so much bigger than anything we know, that not even the wisest of wise men can really make a picture in his mind of how big that cloud must have been. There it was, however. Enormous though it was, it was only a cloud. If we could have been there to see it we should not have found much to say of it, except simply that it was there and that it was very big. All parts of it were like all other parts. It was just a cloud, and if you had tried to draw a map of it you could only have drawn its edge all round, for there was nothing else to draw in it.

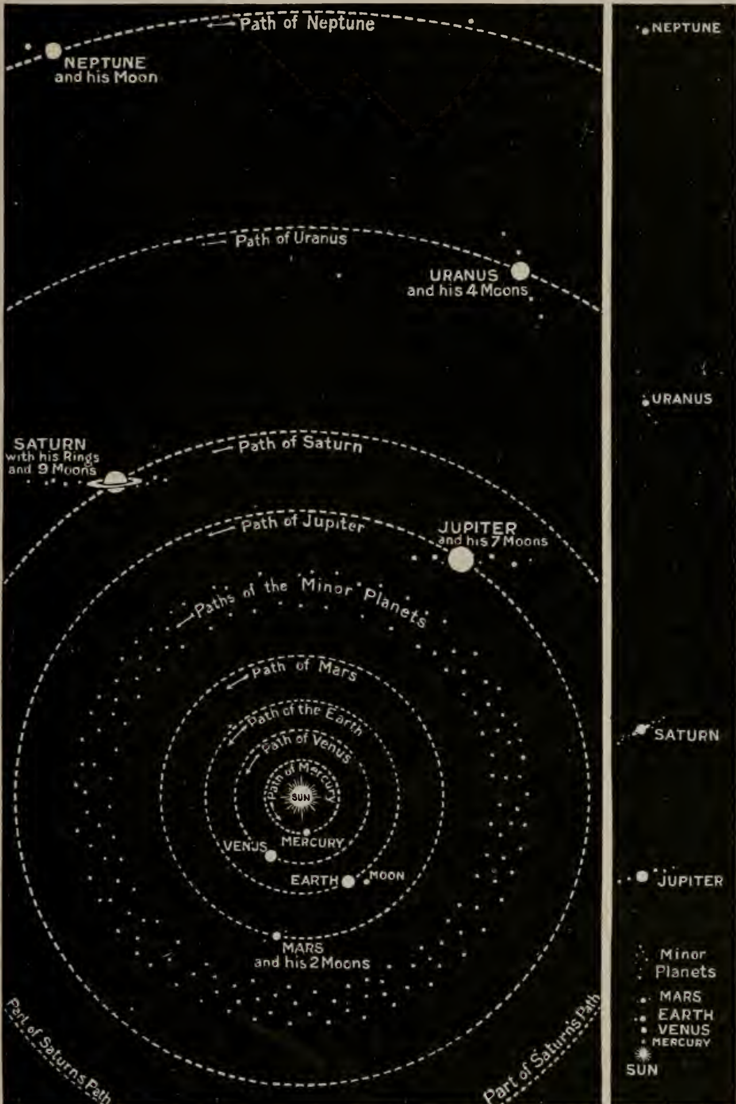
The atoms that we are made of was in the great cloud

Some people think that it must have been a very bright and even a very hot cloud, giving out light and heat from itself; but most people think that this was not so, and that at first, at any rate, this cloud was not bright or hot, but perhaps very cold.

Now you probably guess what is coming. That great cloud was made of the stuff which now makes up the sun and the planets, including our own earth, and even the atoms of which your body is now made, and the stuff which is before you and which you call paper. All the stuff, or matter, as it is called, that now goes to make the solar system—the sun and its family—was there in that great cloud. There was no system, however. The cloud had no particular shape, and one part of it was just like another.

There was only this to be said—if we, and not merely the matter of which

THE SUN AND ITS NUMEROUS CHILDREN



The sun is like a great furnace of heat and light in the center of the universe. Around it travel a wonderful family of worlds, which we call planets. They all go round the sun in the same way, but some members of the sun's family are so far away that it takes them many years to go round it. The earth goes round the sun once in a year, but Neptune, the most distant planet, goes round only six times in 1000 years. The picture at the right shows the size of the planets compared with one another, and their distance from the sun.

our bodies are made, had been there to say it—and that is that all the little bits of which the cloud was made up were moving. They were probably rushing about in a very rough-and-tumble sort of way. Nothing could have been less like a system of any kind. This all happened so long ago that we simply cannot think how long ago it was. But, as the ages went on, all the little bits of stuff that made up the cloud found themselves moving, not like a jumble, but in a more orderly way. Indeed, so orderly was their movement, after a long time, that the whole great shapeless cloud slowly began to twist or spin on itself.

When the spinning of the earth began

Now that reminds you of the earth spinning on itself, and so it should, for the slow spinning of this great cloud was the beginning of the spinning that makes our night and day. The stuff that makes the earth was set spinning in that cloud, and it has been spinning ever since; it is spinning now, and in the same direction as when it first began. But there is no earth yet, nor sun, nor solar system; there was merely this spinning cloud.

As time went on it began to shrink. This we can be quite sure of, for we know that every speck of matter in the whole world tries to attract every other speck of matter in the world. That is why a ball falls to the earth when you let it go. Now, if in this enormous cloud all the little parts were pulling upon each other, of course it would shrink, for those on the outside would have all the others pulling them inwards and none pulling them outwards.

We have made up our minds to try to find out where the sun and the earth come from, and what they were like at first, But before we do that we must look for a little while at what we may call the brothers and sisters of the earth—heavenly bodies that began as the earth began, and that depend upon the sun in the same way. These heavenly bodies, together with the sun and the earth, make up a little family which is complete in itself, and is, in a way, independent of the rest of the world. This little family, since its center is the sun, the Latin name for which is *Sol*, is known as the solar system. What, then, are the other bodies, not unlike the earth, that go to make up the family of the sun?

Ages and ages ago, men who watched the face of the heavens found that among the stars there were some few which behaved quite differently from the rest. All the heavenly bodies, of course, seem to rise in the east and set in the west; but that, as we have seen, is simply because the earth, from which we behold them is rotating the other way. Apart from that movement, which is only apparent and not a real movement, men found that all the heavenly bodies except a very few were fixed in their positions. If we take, for instance, the stars that make up what the ancients called the "Great Bear"—part of which we often call the "Plow"—we find that, year after year, they are always found in the same position. The brightest of the stars had their place in the heavens noted thousands of years ago, and, so far as we can tell without very careful study, they occupy just the same places now. We have lately learned that really they are moving, but they are so far away that, to the unaided eye, nothing can be noticed even in the course of many years. These stars, then—that is to say, all the stars except a very few—were called *fixed stars*.

On the other hand, one or two bright stars could be seen, including even the brightest of all the stars, that were quite different in the way they behaved. They were not fixed, but moving, and their movement could be seen quite easily from day to day or week to week. In one month you might see one of these very bright stars seeming to lie in one part of the sky, but in another month it would not be there at all. Therefore, a special name was given to these stars which moved or wandered about the heavens, and which were, therefore, so very different from the fixed stars. They were called *planets*, which is simply the Greek word meaning "wanderers." Among them was, for instance, the morning star, or Venus, which outshines all the fixed stars; another was Jupiter; and another, because of its reddish color, was named after Mars, the god of war.

These planets are quite different in every way from the fixed stars, and from age to age go on circling round the sun just as the earth does. The planets are not stars at all; compared with the fixed stars. They are so bright simply because they are so near us. More than that, they do not even shine by light of their own, but only by the light of the sun, which strikes upon them, and then is thrown back to us upon the earth, just as a ball is thrown back from a wall. The planets owe all their light to the sun, and if we were upon one of them we should see the earth shining in the sky very brightly and behaving like a planet. Indeed, the earth is one of the planets, and shines by sunlight just as they do.

All the planets, then, including the earth, circle round the sun and make up the family which we call the solar system. This solar system is very much alone in the great world. The very nearest of the fixed stars is so far away that the light by which we see it has actually taken three years to reach us, and light travels so fast that it would go eight times round the entire earth in a second.

All these planets move round the sun, but some of them are much nearer to it than others are. Two of them, we know for certain, are nearer the sun than the earth is. All the rest move round the sun at distances greater than that of the earth.

Now what about the moon, you will say. Well, there is no doubt at all that the moon goes round the earth just as the earth goes round the sun. So, of course, the moon goes round the sun, too, only instead of going straight round as the earth does, it has to keep on circling round the earth all the way. The moon, then, is part of the solar system. Then we have to ask ourselves whether any of the other planets have moons, and the answer is that they have, so that all these moons must be included in the solar system.

It is not very long ago since the first of these moons were found. They were discovered by a great Italian named Galileo. Galileo looked at the great planet called Jupiter, the biggest of all the planets, and there, with the help of his telescope, he saw what no one had ever seen till then—four tiny moons. As he watched them from night to night, he could see quite plainly that they were going round Jupiter, just as the moon goes round the earth. Sometimes one of them would disappear altogether because it had got behind Jupiter, and then it would turn up again on the other side from where it was last seen. These moons went round Jupiter at different distances from it, just as the planets go round the sun at different distances from it; but they all went round in the same direction.

Since that time moons have been discovered going round many of the other planets. So all these moons must be included in the sun's family. The two planets that are nearest the sun have no moons; then comes the earth, which, as we know, has one moon. Some of the planets which go round the sun at a greater distance than the earth are better off. The wonderful planet called Saturn, for instance, has nine moons, and four more moons of Jupiter have been discovered since Galileo's time, so that this planet is pretty well off with eight. The last two of these were found only a few years ago, and perhaps there may be more.

THE WORLDS THAT FLY ROUND AND ROUND THE SUN

Now I think, we must have a list of the planets that make up the solar system, and we shall name them in the order of their distance from the sun; also we may put opposite each planet its distance from the sun in miles, the time that it takes to go round the sun, and the number of its moons.

Names of Planets	Miles from the Sun	Length of its year		No. of Moons
Mercury	36,000,000	88	days	0
Venus	67,000,000	224	days	0
Earth	93,000,000	365¼	days	1
Mars	142,000,000	686	days	2
Jupiter	483,000,000	12	years	7
Saturn	870,000,000	29½	years	9
Uranus	1,754,000,000	83	years	4
Neptune	2,792,000,000	165	years	1

If you look at the second column you will see that we have called it "length of year." Now, you understand that what we mean by that is the length of time the planet takes to go right round the sun, and we measure that by the units that we on the earth know best. So, when we say that the length of Neptune's year is 165 years, what we mean is simply that while Neptune goes round the sun once the earth has gone round it 165 times.

HUNDREDS OF TINY PLANETS AND "STARS" WITH TAILS OF FIRE

But even this is not the whole of the sun's family, for we have lately found some very tiny little planets, far smaller than the moon, which go round the sun between the orbits of Mars and Jupiter. All of them put together—and they are numbered by hundreds—would not be nearly as large as the earth. At one time it used to be thought that all these tiny little bodies had been formed by the breaking up of some big planet; but nowadays men are very far from sure that this "shattered planet" ever existed. However, all these little bodies have to be included among the sun's family. They are all found, be it remembered, in one particular part of the solar system, and doubtless, if we could discover the history of any one of them, that would also be the history of all the others.

Yet again, the solar system includes a number of strange and wonderful objects which are utterly different from any of those we have described; they are called *comets*, from the Greek word for hair, because when we can see them best they seem to have long hairy tails streaming out across the sky. These also travel round the sun, and therefore belong to its family; but they do so in a very curious way. None of the planets go round the sun in circles, but always in paths like a circle that has been rather flattened in one direction.

In the case of the comets, however, this flattening is very extreme. At one time in its history the comet is quite close to the sun, and just misses running into it. Then, after passing round the sun, it travels away from it, out and out, cutting across the paths of all the planets and passing millions of miles beyond even Neptune, and then at last it turns on its course

This picture helps us to realize what our minds can hardly understand—the wonderful size of the universe, and the immeasurable distances in space. The artist has drawn an imaginary railway line leaving the earth for the planets, and the figures on the trains give the time it would take the trains, traveling all the time at sixty miles an hour, to reach the planets and comes back again. But still it is one of the sun's family.

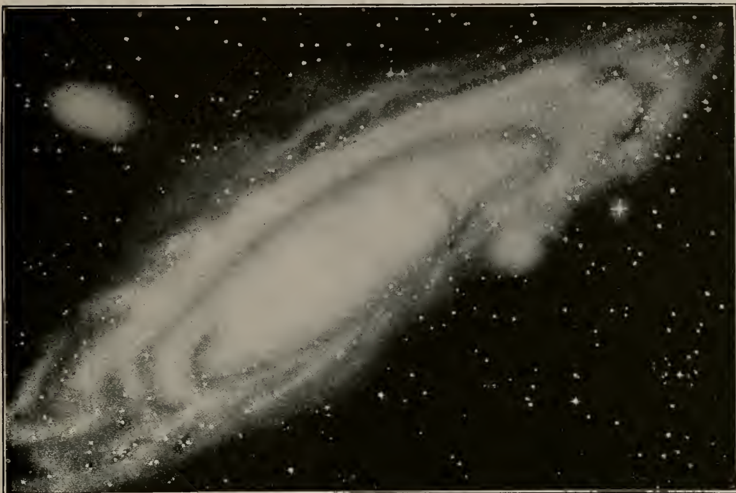
THE BRIGHT LIGHTS THAT SHOOT ACROSS THE SKY

Now even this is not quite all. You must have heard of what are called shooting stars, and on any clear night in November you will very likely see some—and also at other times of the year. A flash of light seems to come from nowhere, dart for a little distance across the sky, and then disappear. These, of course, are not stars at all, but quite small things, perhaps the size of a football, which the earth has caught as it flies through space, and which, as they pass through the air, are made very hot and bright. What is left of them often may reach the earth, and many of them are to be found in museums nowadays. It seems that throughout the solar system there are countless numbers of these small objects called meteors. These meteors also circle round the sun and belong to its family. In November the earth is apt, in its path, to cut across the path taken by a very large number of these tiny wandering bodies, and that is why we are most apt to see shooting stars in November.

A very interesting fact is that a famous comet, the path of which was well known, disappeared some time ago, and just in that same path we now know that there are a number of these small bodies like pebbles. There can be little doubt that they are the remains of the broken comet.

Now we have completed the strange list of the different kind of things that make up the solar system: Sol, the sun itself, in the center, the planets round it, the moons of the planets going round them, the very small planets found between Mars and Jupiter, the comets, and a host of little things like pebbles. All these make up one great family ruled by the sun. So far as we can find out, they practically all move in the same direction round the sun; they twirl or twist on themselves as the earth does, also in that same direction; their moon goes round them in that same direction, and even the sun is twisting in the same direction also.

This solar system is very much alone in the great world. But it does not stay in one place. We know that the sun—and with it all the planets and moons—is moving through space at a great rate of about twelve miles per second. Though the solar system is very much alone in space now, we have no reason to think that it was always so, or that it will always be so.



The earth began, as far as we can tell, in a great shapeless cloud like this. All the matter of which the sun and its family of worlds are made was in this cloud, which moved through space for millions of years, until parts broke away. The parts shrunk into themselves and became globes, like the earth and the moon opposite.

HOW THE EARTH WAS MADE

This story tells us of the time when the sun and its family of worlds were all one—a great fiery cloud, which at last broke into smaller clouds. One of these was the cloud that formed the earth, which became at last a glowing globe of gas, hot at the center and cooler at the surface. Slowly the gas became liquid—like water, but red hot. There was then no living thing on the earth, which was like a red-hot ocean. As the earth spun round in space an extraordinary thing happened: part of the red-hot stuff fell away, like drops from a wet umbrella, and formed the moon. Slowly the globe cooled down and the hard surface of the earth was formed—the great ball of earth, still glowing inside perhaps, on which we live.

AND now we must ask ourselves again the great question: Where have the sun and the earth come from, and what were they like at first?

For a long time men used to think that the solar system, including the sun and the earth, had been, from the first, as they are now. No one now thinks that, however. We believe that they have grown, so to speak, to be what they are, and we have a fairly good idea of the way in which they have grown. Now, in order to see what the solar system was like at first, we have only to take a telescope and look up at the sky, and there we shall see scores of thousands of wonderful bodies which are still at the stage the solar system was at long ages ago. These bodies are called nebulæ, and one of them would be called a nebula, which is simply the Latin word for a cloud. They look like the tiniest little bright, fleecy clouds in the sky. Some of them can be seen with the naked eye, and then they look like stars, but they are quite different from stars.

We now know for certain, by examining the kind of light that they send to us, that the sky contains, at the very least, 120,000 real nebulæ. They are not star-clusters at all, but glowing clouds of matter. Perhaps you can get the best idea of what a nebula is like by using the name which the poets often call it by, and that is fire-mist. A nebula is like a great mist of fire. Those we see in the heavens are of different shapes and sizes. Many of them are far bigger, hundreds or thousands of times bigger, than the whole space occupied by the solar system. A great many of them, probably about half, have a shape very like a lens. They are called spiral nebulæ. You know what a spiral staircase is. The spiral nebulæ, however, ought never to have had that name, because they are not at all like a spiral staircase; they are quite flat, thin things, much more like a lens in shape.

If we look at some of these spiral nebulæ we see bright points in them here and there, which suggest to us that the fire-mist has become thicker at certain places than at others. Often these bright points are so large and bright that they look like stars, and, indeed, probably they are stars. Probably all stars are made out of nebulæ. Now let us come back to our solar system.

If you could look at the solar system from a great distance away you would notice many remarkable facts about it. In the first place, you would notice that all the twistings and movements are in one direction, as we have already said; then you would notice that the solar system is a flat thing. All the planets, so to speak, go round the sun at much the same level. You know that if you took two hoops you might put one inside the other, so that while the one hoop was upright on the pavement the other lay across it; then anything traveling along the rim of the one hoop would be traveling round and round, and anything traveling along the rim of the other hoop would be traveling up and down. Now, that is just what we do not find in the case of the solar system. It is a flat thing like a system of hoops of many sizes, all laid on the ground inside one another; and the spiral nebulæ are also flat.

Now, there is another curious fact, and this is that the kind of matter the sun is made of is the same as the kind of matter that the various planets are made of. It almost looks—does it not?—as if our little earth and all the planets were once a part of the sun.

THE SUN IS MADE OF THE SAME MATTER AS THE EARTH

And so men guessed that perhaps the pieces of matter that now make the planets have been somehow brushed off from the sun, and that as they cooled down they had become solid and started traveling round and round it.

We are sure now that that is not what happened, but we are also sure that the idea underneath that notion was right. The sun and all its planets were once one.

Indeed, we believe that in its first stage the solar system was nothing else than a nebula, like one of the very smallest of the thousands of nebulæ that we now see in the sky. No one who has studied the subject now doubts that; still we are not certain as to exactly how such a nebula would gradually become changed into the solar system that we know. It seems to be certain, at any rate, that a nebula is apt to become flattened and also to take on the shape of a lens. Far too many of the nebulæ are of that shape for us to imagine that there is not some good reason why they should be so. Possibly if we could live long enough to watch the nebulæ that are not spiral we should see them gradually become so.

Now there is one great fact that must always be true of a nebula like this. It is a fact which is true everywhere, and it is not difficult to describe. We are certain that in the course of time this fact must work great changes in a nebula—such changes as we believe to have been worked in the nebula from which the solar system was formed.

What happened when Sir Isaac Newton saw an apple fall from a tree

This fact is called gravitation, and it simply means that every tiniest piece of matter, or stuff, in the whole world has a natural tendency to attract and be attracted by all the other matter in the world. Gravitation is, perhaps, the most familiar of all facts in our daily lives. When you let go of a ball it drops to the earth, and that is simply because the earth and the ball have attracted each other. The ball is so small that it moves the earth to itself only a very little distance, and what we see is simply that the ball falls to the earth. One of the greatest men who ever lived, an Englishman named Isaac Newton, it is said, was lying on his back, under the shade of an apple-tree in his father's garden. He was not just dreaming his time away, however, but thinking; and he saw what thousands of people had seen before him, but never troubled to think about—an apple falling from the tree to the ground.

The result of his thinking about this was that he discovered this law of attraction, which is true throughout the whole wide world, not only of the earth and a ball or the earth and an apple, but also of the earth and the moon, the earth and the sun, and also of all the atoms, or matter, in a nebula.

How the great cloud began to come together and form the earth

From the first moment that a nebula was formed, then—probably by a collision between two or more stars—there would begin to act upon all its parts the same force of gravitation which acts upon you if you miss your footing and tumble downstairs. And this is a force that goes on acting all the time, never ceasing and never getting tired. So, some years after the great work of Newton, several men began to apply his ideas to the nebulæ and to ask what must happen in the course of ages when this force of attraction acts upon such a nebula.

Herschel, the man who made a list of the great stars

One of the greatest of these followers of Newton was Herschel who made finer telescopes than anyone had used before, and who spent all his life studying the stars and the nebulæ. He was the first man who ever made a list of nebulæ and he it was who first saw that they may be arranged in classes, from those which look just like little milky clouds and nothing more, to those which are really stars with a sort of cloudy substance round them.

So it seemed to him that some "clustering power" must be at work turning these scattered and milky nebulæ into brighter and smaller objects which would some day become stars or suns and solar systems. Herschel compared the heavens to a rich garden containing plants in all stages of their lives. This gives us the advantage, he says, that at one and the same time we can see all the different stages in the history of plants—from their birth to their death; so also in the heavens we can see all the different stages from a nebula to a star. Then there followed a great Frenchman who saw that the "clustering power" must be gravitation, and who worked out exactly what must happen in such a case, since we know exactly the force with which gravitation acts.

The earth may once have been shaped like a pear

That, then, is all that we can tell at present about the origin of the sun and its family. Men who work at these things are constantly filling in little details, explaining the small difficulties and helping us to gain a complete picture. But everyone is agreed that something like what we have described is what really happened.

Now let us try to imagine what our own earth must have been like in its beginnings. The most important facts we can be quite sure of, even though we are not quite sure about every step in the way in which the earth first came to be separated from all the rest of the family to which it belongs. We cannot be quite certain as to the shape of the earth at first, though some men who are studying this matter just now think that it may have been shaped like a pear instead of like a flattened orange, as it is now. But, at any rate, whatever its exact shape was, it was so utterly different from the earth we know that we can scarcely imagine it. Really, the earth of long ago must have been far more like what the sun is now—only, of course, quite tiny compared with the sun.

The air is part of the earth and moves with it

The earth, as we think of it now, is something that stops suddenly at the surface—at the level of the ground. That is, however, by no means quite correct. Even now the earth does not stop sharply all round as an orange does. We must not imagine that the earth stops at the level of the ground or at the level of the water, and that we are really walking outside the earth.

Not at all. Above both the ground and the water there is something which is really part of the earth, though we cannot see it. It moves with the earth round the sun, and twists round with the earth as it spins. The stuff of which it is made is constantly being exchanged in both directions with the water of the sea and the stuff of which the dry ground is made. In short, the air is part of the earth, and if we lived on another planet, and looked at the earth from afar, we should never question this for a moment. The air as it is at present probably extends upwards from the surface of the solid and liquid part of the earth to a distance of about 100 miles. As we pass upwards through the air in a balloon we find the air becoming more and more thin, or, to use the proper word, more and more rare; and though we cannot go very far in a balloon, we are quite sure that this rareness goes on increasing until there is no air to be found at all.

When the earth was a great glowing globe of gas

So even now, you see, the earth does not really stop short sharply anywhere, but its matter is spread out all round it in a layer, which gradually becomes rarer and rarer, until at last it stops altogether.

Now, that was certainly true of the earth long ago, and no one who could have seen the earth then would have had any doubt at all that the air was part of the earth; for the earth then did not consist of anything at all like what we call "earth," but it consisted altogether of gases like those of which the air is made today. If you take anything you please and make it hot enough, you will be able to turn it into a gas; and the earth in its beginnings was so hot that all the stuff in it was in the form of gas. Even the stuff that now makes the hardest rocks and stones, not to mention every drop of water in the sea, was then gas.

What we now call the earth was at first nothing more or less than a great globe of glowing gas. In that hot, twisting, glowing globe there were contained all the tiny little portions of matter, or atoms, as they are called, which now make up the water of the sea, the soil, the rocks, the bodies even of all living things, and also, of course, the air, or mixture of gases, that still remains covering the whole earth like a warm blanket.

WE LIVE AT THE BOTTOM OF AN OCEAN OF AIR

So far are we from being really on the surface of the earth that the whole earth, sea and land together, is really covered with a great sea or ocean of air. We move about at the bottom of this ocean, and the thing we are puzzling our heads about just now is how to learn to jump off the bottom and swim in it, as birds have been able to do for ages without troubling their heads at all.

In the course of time we know that great changes had to happen in this glowing globe of gas. It was doubtless then giving out light and heat like a little sun, but in doing so it would gradually become cooler. If you make a poker red hot, and then take it out of the fire, it will give out light and heat for some time; then it will give out heat only, but no light—which is to say, that it is still hot, but will have become dark; and lastly, it will become quite cold. It cannot give out light and heat without becoming cooler itself, for it does not make them out of nothing. The case was the same with the earth, and in the course of long ages it had gradually to become cooler. At last it would have to become so cool that part of the matter of which it was made would no longer be a gas, but would become liquid, like water. This is a perfectly simple thing which you have seen for yourself a hundred times—whenever you look out of a railway car, for instance. As you breathe, a great deal of water comes out of your mouth and nose. This water, having come from the inside of your warm body, is itself so warm that it is in the form of a gas; but when this warm gas strikes the cold glass of the window-pane it is cooled so much that it is turned into a liquid, and will run down the pane in little drops. If you cool any gas sufficiently, it must become liquid.

Now, that part of the earth which would soonest become cooled would not, of course, be the hot inside—which is believed to consist of a gas at this very moment—but would be the part next the surface. All the kinds of matter that were most apt to become liquid would do so, and, being heavier, would fall towards the center; while the kind of matter, like the air of today, which is not so apt to become liquid would stay where it was.

THE RED-HOT TIDE THAT ROLLED OVER THE EARTH LONG AGO

So you can imagine an earth with a core of hot gas and a layer of liquid outside that, and then a layer of cool gas, or air, outside that. But soon even part of the matter that had become liquid would become solid, or perhaps like a very thick oil.

Now, it must be remembered that all this time the earth was twisting round and round like a top, as it has done ever since, and as it is doing today. Also it must be remembered that the great sun is all this time pulling as hard as it can upon the earth by means of gravitation. You can imagine, then, that the liquid stuff next the sun at any given moment would be apt to be pulled out towards the sun or heaped up at the surface of the earth. But, of course, since one point of the earth is never opposite the sun for long, this heaping up of the liquid on the surface would be like a wave traveling over the surface of the earth. Now, this great traveling wave is nothing else than a tide, and every child who has ever been to the sea has seen its consequences. Only the first tides that were raised by the sun upon the earth were not tides of cold water, for there was no liquid water upon the earth at that time at all.

The earth was too hot for that, and all the water in it was in the form of a gas in the air, just like the water in your warm breath before it strikes the cold window-pane. The first tides that rolled upon the earth must have been terrible tides made of something like red-hot lava—the red-hot stuff that comes out of a volcano and runs down in fiery streams until it turns cold and solid.

How the Moon Was Flung Off from the Spinning Earth

Now, it is much more than probable that a very remarkable thing happened somewhere about this time. The men who have studied this subject believe that one day, while these tides of lava were rolling round the earth as it spun, part of the lava was whisked off like drops from a wet umbrella when you spin it. It is even possible that two great lumps were whisked off at about the same time—one from one side of the earth and one from the other. Perhaps at this time the surface of the earth had become cool enough for the great gaps left by this loss to remain more or less fixed, and some people have supposed that those gaps are now the great bites into the surface of the earth which have since been filled by the seas. They would not be filled with water then, because the earth was doubtless still so hot that all the water remained in the form of a gas in the air.

But what became of the lava that was so whisked off from the surface of the earth? Its shape at first, of course, would be very irregular, but as it went on moving and became cooler, and as its parts acted upon one another by gravitation, it would become round.

The Distance of the Moon, Our Nearest Neighbor from the Earth

Now, surely, with all these hints, you do not need to be told that it is the moon which men believe to have been formed from the earth in this wonderful way. At first it was very near the earth, and for a long time afterwards it went gradually farther and farther away. But even now the moon is really close to the earth, not so far off as ten times round the earth.

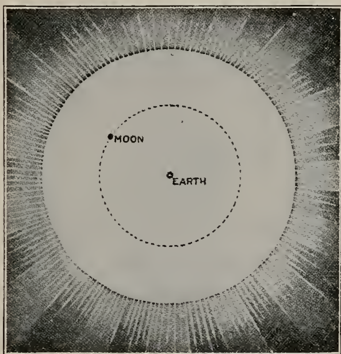
Though, compared with all the stars and suns and planets, the earth is only a grain of dust, yet it is to us the most important part of the whole universe, and we are right to think so. Therefore we cannot know too much about it. We read here of the earth's crust and its inside, and we begin to learn how the world is kept warm.

THE EARTH AS IT IS TODAY

SO far we have been going over a kind of history, showing very briefly the chief things that have happened in order to make the earth of today. But we have seen also what people are so apt to forget—that the things which went on in the past are going on still; the earth, which is the product of changes, is still changing.

We shall not talk here about the oceans and the seas and continents and mountains—what is called geography. That is important, and we shall come to it in its proper place and at the proper time. We must begin now by thinking of the earth as a ball, speaking about it just as one might speak about a base ball. Perhaps you know that a base ball has a certain weight, that it has a cover, and that inside this there is a core, which is made of certain materials put together in a particular way. You may also know that a base ball is elastic, so that when you throw it against a wall it comes back again instead of spreading out and sticking to the wall, as a lump of mud would. Now, just in the same way let us examine the great earth-ball, tiny little pieces of which we put together to make base balls, cathedrals, and other things.

We have mentioned what the size of the earth was. Now, we have a good idea of what a yard is and what a mile is, but it is very difficult to imagine such a distance as 25,000 miles; yet, though this sounds such a big figure, compared with other things, the earth is really very small. If the center of the sun could be placed at the center of the earth, the surface of the sun would reach far beyond the distance that the moon is from the earth—that is to say, the sun occupies far more space than the whole of the space swept by the earth and the moon moving round it.



The sun is so much bigger than the earth that if the sun could be placed at the center of the earth the outer edge of it would reach as far beyond the moon as the moon is from the earth. It is four times as far across the sun's face as it is from the earth to the moon.

And yet the sun does not look so very much bigger than the moon, though really you might throw a thousand moons into the sun, and the difference they would make would not be worth mentioning.

THE EARTH'S CRUST

If we turn to the earth and study the crust under our feet, we are able to find out many important facts concerning it. Men dig mines in the earth, they make deep borings into it, they study the sides of its canyons and gorges, they climb its mountains, and little by little they have been able to piece together the scattered facts about the crust, until at last a great deal is known about what happened here upon the earth long before man appeared upon it.

This study of the earth and its history is called geology, and it has been necessary not once, but often, to refer to it in these pages. We have learned a little about the part that water plays in the history of the earth; we know that there are rocks which were formed under the influence of heat, that there are others, which were formed by water. We shall now make a survey of some of the main facts and ideas of geology, enough for us to be prepared to study the earth with intelligence and to follow the work of geologists with interest and profit.

We sometimes read accounts of great earthquakes, such as that which happened a few years ago at Messina, which shake whole regions, destroying cities, towns and killing many people.

Great volcanic eruptions occur which overwhelm large areas and bring ruin in their train. Now it is the earthquake, the eruptions of volcanoes and other violent occurrences, which occasionally happen, that tempt us all into an utterly wrong idea of the earth's history. We are apt to think that it is the violent, exceptional occurrences that have made up the history of the earth, or, at least, that have been the chief factors in it. We see the rain falling, the rills of water rushing down the road, the river flowing in its valley, the waves dashing upon the shore, we notice the wind blowing or the dust flying over the fields. It is not easy to imagine that such things, apparently so slight in their effects and so slow in their action can accomplish much. Yet it is these rather quiet activities that have had most to do with the present shaping of the crust and not the violent earthquake or the volcanic explosion. When we cross a stream or note the rain falling upon the soil, or when we play with the sand on the seashore we can see and watch for ourselves the slow happenings which have made, are making and will continue to make the features of the land upon which we dwell.

THE FORCES THAT MAKE THE CRUST

The crust of the earth, too, is not stable, it is not *terra firma*, as we sometimes call it, but it moves now up, now down. At times portions of the continents are depressed beneath the sea, sometimes raised above it. These movements are exceedingly slow, so much so that we do not notice that any change is taking place.

Our lifetime is too brief to enable us to realize that any movement is happening. If the land rises up high above sea-level then the streams, the atmosphere begin to attack it; if time permits they may wear it down almost to sea-level again. The erosion of land into hills, valleys, plains and mountains is more rapid when the lands are being elevated and less rapid when they are depressed and approach the level of the sea. These movements of the land give the opportunity for rain, frost and other agents to carve and develop the scenery, which surrounds us.

Another important fact in connection with the study of geology is that it is a historical study; it tries to present to our view all of the important events of the earth's history in the order of their occurrence, it also attempts to enable us to see what was happening during the long ages before human beings had appeared.

It tries to show us how large the continents were millions of years ago, what their shape was at that distant time, what mountains existed, what plants flourished, what animals lived and where.

THE WONDERFUL SUCCESSION OF CHANGES IN THE EARTH'S STRUCTURE

We realize that human history is always in the process of making, it is being unfolded as we read these pages; it is just as true that the rain, the wind outside at this very moment are helping to make the history of the earth's crust. The history of the earth, then, like the history of man, is really made from moment to moment, by small things, which do very little in a moment of time but do accomplish much in a million years. Geology teaches us that time is very long, that the earth has existed through such vast periods that the human mind is unable to grasp their immensity of reach.

The earth has had its being for tens of millions and probably for hundreds of millions of years. If we might only see that wonderful panorama, which has been unfolded here through all of these long ages. We know something about it, through the efforts of geologists, but not in all of its beauty, grandeur and interest.

What continents have existed, where now rolls the sea, how oceans have spread out and covered areas, now dry land; what great forests have waved where now deserts and plains extend, what endless troops of animals have crossed and recrossed the continents, animals of such strange appearance and structure that we would be astounded beyond measure should we meet them in the flesh! What successions of beautiful sunrises and sunsets have flashed their beauty on the world, what great canyons, with their gorgeous colorings have seamed the crust, what stupendous mountain peaks, glittering with snow and ice, have lifted their heads in air! No human eye saw them, their beauty went for naught so far as man is concerned, yet they were here and their fleeting glory, their majestic presence, have been a part of the record of old mother earth and her vast, far-extended history.

These are some of the lessons which geology has to teach us and now we may go on to look at some of the main facts regarding the earth's ever changing crust. The term crust is a relic of the old idea that the globe had a molten interior, which was covered by a thin but solid, compact covering, to which the name crust was naturally applied. This theory is no longer believed, but the old term is still retained and is likely to remain in our current language. Geologists call the crust "the lithosphere," because it is composed chiefly of rocks of one kind and another; these rocks continue down as far as man has ever been able to study the crust.

ROCK STRUCTURES AND ORIGINS

Rocks everywhere underlie the surface of the earth; they are as a result the foundation upon which we live and carry on our activities. The rocks are composed of minerals, united together more or less compactly into masses of varying size. The rocks have one of three origins, as follows:

Some of them were once molten and have gradually cooled from that melted state; sometimes they cooled on the surface of the earth, sometimes they were injected into previously existing rocks and cooled there below the surface. Such rocks are called igneous rocks. Granite is a common type of such rocks; another form is the dark-colored, fine-grained rock usually found on lava plains or plateaus, called basalt, or trap.

Most of the rocks on the surface of the globe belong to the second group, the sedimentary, often called stratified or aqueous rocks. These rocks are laid down by the agency of water, hence the term aqueous rocks; sand-stones, limestones, mud rocks or shales are examples of this group. They are commonly arranged in layers or strata.

The third group of rocks arises from the fact that the igneous or the stratified rocks may be changed by heat or pressure, they may be so folded and crushed, so altered as to lose their original appearance, perhaps they may be so changed that they are no longer recognizable as either igneous or sedimentary in origin. Such rocks are called metamorphic rocks. Marble is an example of a metamorphic rock, which has been changed over from a limestone; slate is a metamorphic rock also, it was formerly a mud rock or shale.

Commonly the solid rocks do not appear at the surface, but they are hidden from view by the covering we call the soil or by other deposits. Though rocks may seem to us to be hard and unyielding, yet as a matter of fact they do not long retain their compact nature; they are attacked by various agencies, they decay, they become broken up into fine particles, which gradually collect to form the soil, or else they are swept away to their final resting place beneath the sea.

Action of Air and Water on Rocks

We should know something about these agents that thus attack the rocks and provide for man that absolutely indispensable product, the soil. In order to understand the methods by which rocks are disintegrated we must borrow help from several of the sciences. We must learn all that men can teach us about the atmosphere and the way it acts upon rocks. The chemist finds oxygen in the air and in water; it is known that the oxygen will unite with the iron in rock-making minerals and cause them to rust and to crumble away. The chemist finds carbonic acid gas in the air and in rain water; he is able to show that this gas, when united with water, helps to dissolve some of the mineral matter in rocks and this causes the rock to waste away. All of this knowledge is a necessary part of geology. The physicist shows us that when water is frozen in a tightly closed vessel, it expands as it freezes and bursts the vessel; so when water freezes in the cracks of the rocks it rends the rocks apart and helps to break them up. This knowledge becomes a part of geology. We must study where we can the action, chemical and physical, of rain and frost, of water on the surface and under the surface; we must study the work of wind and waves, of glaciers, of ice on lake and river; these are all tools engaged in breaking up the rocks of the crust. If we watch these agents at work day by day, if we study the results of their activity, we may know why the crust is so altered from period to period and why it has its present form.

Geology also borrows from the student of earthquakes and of volcanoes and learns to know what these dreaded powers have done to make the earth as it is. Geology is the great borrowing science, had it not been for the things geologists have obtained from other sciences, little would be known about the earth and geology would not be the important study that it now is.

The Forming of Minerals

But the borrowings of geology are not yet ended; it must learn from the mineralogist about minerals. It must take everything that mineralogy has to teach about crystals, about minerals, how they are formed, how they break up, how they melt down, how they are dissolved and by what, how hard they are and how much they weigh. Not only this, but we should learn about where minerals are found in the earth, how they lie in veins, in cavities, in masses; all of this knowledge comes to form a part of geology. Nor has this exhausted our sources of knowledge, for everything we may learn about plants and animals contributes to geology. The rocks have records of many forms of life, some of which are utterly different from any now existing, while others are scarcely different from those now living.

If we are to understand this life of the past it is necessary to use the knowledge furnished us by botany and zoology. Geology gains enormously from a study of these remains in rocks just as the study of biology gains greatly from geology.

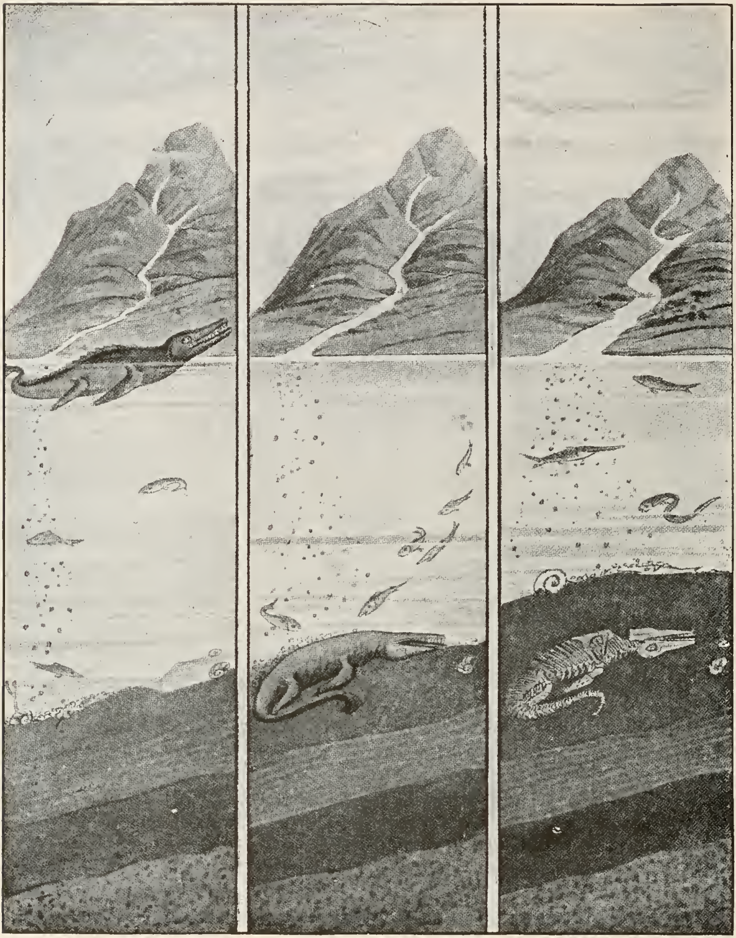
By the use of these sciences geologists have learned much about the crust, about the rocks which compose it and about the long history through which they have passed. This history is told by the structure of the rocks themselves and also by the fossils in the rocks; it is a twofold presentation and we shall now consider each of these sources of information. The rocks tell, in a measure, the experiences through which they have passed. The mud, the sand and gravel, which form many rocks, show the conditions that were in existence, when they were forming. We may know, for example, whether they were formed under the sea or on the continental surface, whether in shallow water, near the shore, or in deep water. The rocks tell the extent of the oceans in which they were deposited. This enables us to determine the size of the continents, also, we may know their general outlines and their relations to each other. The rocks enable us to tell whether the continents were mountainous at any given period or whether they were low-lying. Many marks are found in rocks, which help to interpret their history and to tell the place of their formation. Ripple marks, rain-drop impressions, sun-cracks, rill marks, tracks of animals, etc., are among the tell-tale evidences that rocks, which contain them, were formed in shallow water or on exposed tidal flats, near the shores of continents.

The structures, which rocks have, also, aids in understanding the changes which have taken place since they were formed. The folding, the crystallization, the erosion which they have undergone all help to tell this long story of change and endurance. The folds in rocks may indicate that they were once a part of a great mountain chain, which has now disappeared. The worn condition of the rocks may enable the geologist to estimate how high they were once uplifted and how much they have been cut down by erosion.

ANIMAL REMAINS SHUT UP IN ROCKS

In many respects the most important story the rocks have to tell us is gleaned from those remains of animals, which lived long ago, and are known to us as fossils. They help to an understanding of the globe because their form and their nature reveal the conditions under which they lived and died. The animals and plants found in the earlier rocks are utterly different from those now living, while those in later rocks are scarcely to be distinguished from many now living. Animals have slowly changed from period to period and they thus indicate the passage of time. In the rocks of each period, too, there are fossils which are peculiar to those rocks and this aids geologists greatly in determining just when the rocks were formed. Unfortunately the rocks have not yet taught us all we may hope to learn regarding the history of life.

THE CHANGING EARTH FROM AGE TO AGE



The history of the earth for millions of years is written in its rocks, and men are able to read what took place, and to give us, in pictures like these, a vivid panorama of the earth's long wonder-story. We can see also just how that story came to be written in the rocks. A million years ago, a little stream trickled down a mountain-side, carrying with it grains of sand and stones, which fell to the bottom of the sea. In the sea swam a great and wonderful creature called an ichthyosaurus.

The ichthyosaurus was a reptile that lived in the sea, and its name means "fish-lizard." It had a great head with powerful jaws and teeth, and its body had four limbs like paddles which enabled it to swim about. One day the great creature died, or probably it was killed in battle with another strange monster, and its body fell to the bottom of the sea among the shells and seaweed. Meanwhile, the stones and sand brought down by the stream continued to fall upon the bed of the sea.

As the ages passed, the stream gradually wore away a wider and deeper bed for itself, and became a big river; and the rains falling upon the mountain loosened the soil and formed hundreds of tiny streamlets. These all ran into the main stream, and each did its part in wearing away the mountain. As the river became wider, so it brought down more and more earth and stones, which fell in a never-ceasing shower upon the bed of the sea, until at last the great reptile's body was buried.

THE WONDER-STORY TOLD IN THE ROCKS

Higher and higher rose the ocean-bed as the mud from the mountain continued to fall upon it, and the lower layers became pressed into hard rock by the weight on top. One day an elephant going to the river to drink broke off his tusk, and this was carried down by the river and sank in the sea. Another day a bird was drowned, and this, too, fell upon the ocean-bed. Dead fishes and shells also sank, and all were buried by the never-ceasing shower of mud and earth and sand and stones.

All through these ages the rain and river were wearing the mountain away. Hundreds of thousands of years after the ichthyosaurus died, men began to live on the earth, and one day a man who had made a boat out of a hollow tree-trunk took his wife and went out to fish. Trying to spear a big fish, the head of his harpoon broke off and fell to the bottom of the sea. It was too far down for the man to recover it, and in course of time this also was buried in the mud.

The bottom of the sea crept higher and higher, till at last it became dry land. Then one day men began to dig, and the world's wonderful story was revealed as we read it here. First the spear-head was found, then the tusk, the bird's skeleton, the shells, the fish, and at last the skeleton of the great sea reptile, all turned to stone and became fossils, a word that means something dug up. It is hard to realize that these fossils found in the rocks were once living, moving animals.

The record of life as preserved in the rocks, in the form of fossils, is very imperfect, yet if we consider how many conditions are necessary for a fossil to be formed and preserved, we shall wonder that so many exist at all. The bodies of many animals are entirely soft, having no hard parts; such animals decay before they become fossilized. In those cases where animals have bones or shells, which might be fossilized, it often happens that they may decay or be destroyed, otherwise, before they have a chance to be preserved. Even if the fossils are once formed it often happens that they are obliterated by different things. Water may move through the rocks and slowly but surely dissolve the fossil, heat or pressure may distort and finally destroy all traces of life in the rocks. Many millions of fossils have thus been destroyed and left no trace of their existence. Another reason why the rock record is imperfect, aside from the lack of a life record, is that only a small portion of the rocks have been studied as yet.

Water and land areas

To begin with, only about two-sevenths of the earth's surface is at present above the ocean. All that we have access to is that found on this comparatively small area, which may not be altogether the most important part of the globe so far as the history of life is concerned. Even on the land surface, only small areas here and there have been carefully studied, more especially western Europe, the eastern portions of the United States, Canada and small regions elsewhere. We have not yet even commenced to study thoroughly one-thousandth part of the land surface of the globe.

The really marvelous thing is that so little inquiry has produced such great results. During the past fifty years thousands of new animal forms have been discovered in the rocks, their nature and their characteristics have been determined, so that we know how they looked in life, what their habits were, how and where they lived. Not a day passes that new fossils are not found and recorded, in a few centuries man will know the life of the past much more fully than he does at present.

It is often hard for us to realize that the fossils which are found in the rocks were once living, moving animals, yet, as Professor Huxley once said, "We have no more ground for doubting that these creatures really lived and died at or near the places in which we find them, than we have for doubt about a shell on the seashore. The evidence is as good in one case as the other."

Now that we have found out something about fossils, we must learn what they teach us about themselves and their surroundings.

What fossils teach

This part of geology has its own special name, palæontology, and men often devote their whole lives to a study of a small portion of it. It is found that life began far back in time with the earliest sedimentary rocks and that it has continued on the globe from that time to this without any interruption. At first there were no animals with backbones, all were invertebrates and all lived in the water. As the ages passed away animals came to have backbones, finally limbs were developed, they gained lungs, and began to live on the land. In the meantime they became more complex and better fitted for a varied life. Most of the simpler animals of the earlier ages reproduced their kind by laying eggs, but the higher animals bring forth their young alive, they suckle them and give them a great deal of care. Thus the higher animals are better fitted to live than the earlier ones, and they have become the important life of the globe, because of this fitness.

Some very large and strange-looking animals have lived and then have become extinct. We only know them by their bones or teeth that are found in the rocks. Geologists make drawings of these animals and thus restore these monsters of old. These pictures, which portray their supposed appearance when living, are based on a careful study of their skeletons. There were once great reptiles walking about the earth, swimming in the sea, or flying in the air, the latter real flying dragons. Some of these huge reptiles, the dinosaurs, were among the largest animals that ever lived; they must have been very strange-looking and alarming sort of animals.

How animals in past ages differed from those of today

These animals, however, were merely big; they had very small brains and little intelligence. They were stupid, sluggish creatures, and in spite of their large size and great strength, they gradually died off and became extinct. Thus animal life tried the method of mere bigness, tried it persistently and thoroughly, and it failed. When these great reptiles were masters of the earth, there were, at the same time, little animals not larger than rats or mice, who made a great contrast to the dinosaurs, not only in size but in appearance, in quickness of motion and in endurance.

Unlike these reptiles, which were covered with armor-like plates or with scales, these small animals were covered with hair, unlike the reptiles they were warm-blooded, they cared tenderly for their young, unlike the reptiles they had large brains in proportion to the size of their bodies, which enabled them to act more intelligently. These animals, the mammals, with the larger brains, higher intelligence, better motherhood, have become dominant on the earth and have superseded the larger and stronger reptiles. The earth is possessed by those who have intelligence and who care much for family relations.

We have seen that animals steadily advance from the simpler, cruder forms of early periods to the better and more familiar creatures of today. This is most strikingly shown in the case of mammals, since we are better acquainted with them than with most of the lower animals. There has been a steady advance of the animal as a whole and also in its different parts. This is true of the brain, which is small and quite smooth in early mammals, but becomes much larger and more convoluted in later animals. In the same way the teeth and tooth structure becomes more complex as time passes. The early mammals tended to have small and rather conical teeth, which have been replaced by the larger, more complicated teeth of modern time, such as the molars, with their large grinding surfaces, their cusps and crests. The foot structure also changes as we pass from early to later time, the number of toes becomes less on the whole; primitive mammals probably had five toes, but these have become reduced in number in modern life, to one usable toe in the case of horses, and of two in the case of cattle, sheep and swine. The foot structure has also become more compact, the various joints better fitted to each other and more securely bound together.

Distribution of animals

Through all of the past ages, animal life has moved back and forth over all lands, it has migrated far and it has peopled widely separated regions. Hence it is true that animals which are found in the rocks of any given region may not have originated there, but may have come, by migration, from some far away point.

Animals have a natural impulse to wander and may move about on that account, but other causes serve to drive them forth from their ancestral abodes. Some of these important causes are: lack of food, change of climate, presence of numerous enemies and the like. Horses and camels were both originally American animals, but migrated to Asia in late geological time, where early man found them and domesticated them. The various elephants, which were so numerous in North America during the ice age and just before, migrated originally from Africa, in all probability.

Many features have acted as barriers to thwart the advance of animals or to swing it aside in one direction or another; mountains, deserts, forests, rivers, act as barriers to some animals, while they may be favorable to other animals. Changes in the continents, caused by elevation or depression, and temperature changes are the most potent influences in regulating animal migrations.

What causes the extinction of animals

Animals become extinct through various causes, a group of quadrupeds will have a life history of a certain length, then they die out and a better fitted group of animals takes its place.

Many factors lead to the destruction of animals now and they have also probably acted in the past. In the case of the mammals, for example, diseases, especially skin disease, are an important means, various insects cause wholesale destruction; scarcity of food causes many to starve, the coming on of extreme climates makes trouble for animals. Severe cold or excessive heat may destroy certain types of animals, very arid climates with their accompanying scarcity of water, are exceedingly destructive to animals, which are unable to migrate.

Animals are often handicapped by unfavorable bodily structures, as small brains, poor teeth, inferior foot structures, and these act adversely on length of life, they cause the early destruction of animals possessing them. Changes in the nature of food, the disappearance of food which animals like, may help to cause the extinction of animals. In the case of herbivorous animals such as the bison or the antelope, the appearance of large packs of wolves would mean the destruction of many, for as the herd diminishes, the survivors are unable to protect their young. These and other factors have acted, in the long distant past, to destroy whole families of mammals. As rapidly as they disappeared, however, their place was taken by others and the stream of life went on without a break.

How we know the beginnings of animal life

It is not possible to trace life back to the beginning in any one locality, because the whole series of rocks are never represented in their entirety at any one place. Rocks of different ages are found at different places and it is necessary to go from one part of the earth to another to study all of the rocks and the fossils, which they contain.

A vivid way of getting an idea of rocks and their contents is to put down in order some of the things we should come across if we began to dig down from the youngest rocks, through the whole series to the oldest. If we began in the northern states, we would be likely to come upon beds of gravel or of clay, the so-called glacial drift. Some of these beds might contain bones of large animals, most of them now extinct, such as the mastodon, the mammoth, the sabre-tooth tiger, the rhinoceros. The skulls and teeth of mastodons and elephants are frequently found in peat-bogs and about springs in the northern United States. Below the drift are the rocks of the Cenozoic era; these are especially well developed in the western states, if we should pass down through them we would find animals resembling our modern horses, wolves, bears, squirrels, etc., and yet differing from them. For instance, these more ancient horses were not as large as those at present and they had several toes on each foot, instead of one, as now. The animals were more generalized then than they are at present, that is, characteristics which are found in several different kinds of animals now, were all combined in one animal then. For example, some of the dogs combined features of the fox with that of the dog, some were like bears and were a sort of bear-dog. Some animals combined the characteristics of horse and antelope, or of elephant and rhinoceros, or of giraffe and camel, while some of the early Cenozoic animals combined the characters of hoofed and clawed animals.

If, now, we proceed lower into the rocks to those of the next era, the Mesozoic, we shall find few of the mammals, but many reptiles, many fishes related to our modern fishes, yet unlike them, many curious mollusks that have no living representatives.

Below the rocks of the Mesozoic we come to the rocks of the Palaeozoic era. These rocks are best represented in the eastern states of our country; should we explore them, we would find coal beds, in many localities, with many representatives of the plants which formed the coal. We would readily recognize the ferns, which had a large part in forming the coal, but much of the vegetation would be very strange to us, it is so unlike anything we have in our modern forests. As we proceed further down, we would find remains of fishes, we would find many shells, most of them unlike modern forms; some of them we might be able to recognize by their general resemblances, but most of them would be utterly strange to us. Such animals as the trilobites and the orthoceratites are examples of these strange animals, all long ago extinct.

Finally we would come down to rocks, which yield no evidence of life and indeed correspond to a time when there was no life on the globe, at least of a kind that could be fossilized. Still lower down we should arrive at the granites and other igneous rocks, which from their very nature preclude life. Here we have arrived at a time, which existed before life was found on the earth, we are at the very basement of the great rock series.

THE VALUE OF ROCKS TO MAN

The rocks are of value to mankind not only because they reveal to him the history of the earth, but because they are of great service to him. They hold many minerals and metals, which man must have; they contain the ground water, so essential to the welfare of plant and animal life and to the maintenance of rivers and lakes. The rocks furnish abundant and valuable building material, they supply ballast for railroads, material for roads, for concrete construction, etc. The soil is supplied from rocks and so in numerous ways man has come to depend absolutely upon rocks for his life and for furnishing the means for his industries.

The earth, being a great ball, has a core, just as an apple has a core; but the core of the earth is made up of vast quantities of burning materials and gases. This central fire, just like any other fire, must find a chimney, and there are many mountains in the world through which the fire forces its way. We call them volcanoes, and they are the chimneys of the central fire. But it is not always smoke they pour out, as Vesuvius, the great volcano of Italy, is pouring out smoke in this fine photo; underground rivers sometimes burst into the burning materials at the bottom of the volcanoes, and so cause great explosions of the most disastrous kind. At times volcanoes burst with great violence, and Vesuvius has destroyed whole cities, one of them, Pompeii, overwhelmed just after the birth of Christ, having been dug out of the earth.

THE EARTH'S CHANGING FACE

PERHAPS the mountains are the objects that would most strike an observer, apart from the question of life—mountains and valleys and inland cliffs and what are called canyons. On the seashore we can watch the sea doing its work upon the cliffs almost any day; but we know that there are cliffs far from the sea, and mighty valleys which look as if they had been suddenly scooped out by some tremendous deluge of water. So first let us study these great ups and downs on the dry land.

Probably we are only just beginning to get a real understanding of the making of mountains. At any rate, we may be sure that the process was a gradual one. We may also be sure that the cooling and shrinking of the interior of the earth is one of the great underlying causes in the making of mountains. The view which is generally held, though we are beginning to suspect that it is probably not the whole truth, is that mountain ranges are formed by the crumpling of the earth's crust as it tries to fit itself to the shrinking interior.

Then, we are now beginning to believe that the marvelous element, radium, which is found everywhere, may possibly, by the power which it produces from inside itself, have had a share in the building of the mountains. But it is impossible to say more about that yet. Let us turn to the places where the dry land, instead of being piled up, is scooped out. Until the first half of the nineteenth century, men always supposed that valleys had been made suddenly by some mighty disturbance, like a great deluge. When we do not see the slow steps of a movement, and when they act for such long ages that the mind cannot appreciate the length of them, we fail to understand how great are the changes they can produce. When it was first taught that long lines of inland cliffs and mighty valleys had been formed, not suddenly, but by the slow working of agencies which are still at work, like wind and water, the students of the subject thought it impossible that this could be, but now no one questions it. The discovery of the truth was the work of the greatest of all geologists, Sir Charles Lyell, who, like many other great men, was abused during his lifetime, but whom all students of the earth will always honor.

There was a time, we know, when all the northern parts of Europe and North America were under ice; indeed, that has been true throughout more than one period of history. No one yet understands the real cause of the Ice Ages, and it will be best not to attempt to explain them. Probably, in a very few years, we shall learn how they came about. But, at any rate, we must know, when we study the mountains, that there were Ice Ages; and it is specially interesting to know that the Ice Ages were quite recent, comparatively speaking.

HOW MOUNTAINS AND BOULDERS TELL US OF THE STORY OF THE EARTH

Charles Darwin says: "The ruins of a house burned by fire do not tell their tale more plainly than do the mountains of Scotland and Wales, with their scored flanks, polished surfaces, and perched boulders, of the icy streams with which their valleys were lately filled." In many parts of Europe we can study the action of ice upon the mountains even at this day. A stream of ice flowing down a valley from an ice-covered mountain is called a glacier. In very cold parts of the world we can find glaciers run right down to the level of the sea; but elsewhere, as for instance, in Switzerland, of course we can only find the ice at a much higher level, say, four or five thousand feet above the level of the sea. In Greenland, as the ice of a glacier breaks at sea-level, it forms icebergs; in Switzerland, when the ice of a glacier breaks, it may tumble down the mountain, and cause what is called an avalanche.

When we talk of a stream of ice, people may say: How can ice flow, and at what rate does it flow? Well, we may say that the rate of flow is a few feet each day, and the central part of the glacier moves more quickly than the sides because they are held back by the friction of the rocks between which it flows.

THE WONDERFUL REASON WHY A RIVER OF ICE FLOWS FOREVER ONWARD

The same is true of any river, and we can also see exactly the same when we watch the blood flowing through a blood-vessel. The reason why the ice flows, as it does, is now understood. The weight of the ice makes it fall, and it is of course pressed upon by snow from above; but the glacier could not flow as it does were it not for the fact that when ice is pressed very hard it is melted, and then, when the pressure is removed, it freezes again.

So, as the glacier moves down, any obstruction in its way causes part of it to melt, and so flow over; and then, when the obstruction is passed, the ice freezes again. This curious property of ice can be shown with a block of ice and a piece of wire, which can be pulled right through the ice and yet leave a solid block behind. The pressure of the wire causes the ice to melt, and then, after the wire has passed, the ice freezes again. The ice that forms the glacier comes from the snow on the mountain heights. As this snow is squeezed and pressed, it turns into ice.

MOUNTAINS, EARTHQUAKES, VOLCANOES

The rocks of the earth suffer many changes and accidents after they are once laid down; these changes produce a marked effect upon the surface features of the earth, or what we may call the face of the earth. Sometimes the rocks are folded into great mountain chains, which cause the face of mother earth to be severely wrinkled; sometimes large areas are directly uplifted, forming plateaus or what may be termed large swellings on the earth's face. Sometimes great fissures traverse the earth, lying more or less parallel to each other, while other sets of fissures or cracks run across them, more or less at right angles to the first set of cracks.

This divides the crust up into great crustal blocks. When earth movements take place, these blocks may move differently, they slide one on the other, some sinking faster than others, some becoming tilted over, some, possibly, becoming pushed up over others. These various movements cause great disturbances in the rocks; they may break apart on either side of a fissure, one side settling down, the rock layers become mismatched, one layer of rock, perhaps joining another of a different sort. When men are mining coal, gold and other minerals under the ground, it is very annoying to come to places like this, where breaks or "faults" occur. The coal bed or the gold vein has been snapped short off by the fault and has disappeared; it may be that it has been carried down by the settling rocks several thousand feet. It becomes a matter of careful study to determine where the vein has gone, how far down it is, whether it will pay to dig down to reach it. Beds of rock with a small fault are shown on page 43.

When these faults occur, great massive rock blocks may drop all at once, this sudden movement produces a jarring of the crust, which may be felt as an earthquake. If the moving mass of rock happens to be large, or if it drops quite a distance, then the earthquake shock is very severe and it causes great destruction of life and property, though generally only over a very limited extent of territory. Sometimes the rock masses move on each other horizontally instead of vertically, this was the case in the great San Francisco earthquake of 1906. These sudden movements and disturbances may result in a sudden elevation or depression of the land over an area of notable size.

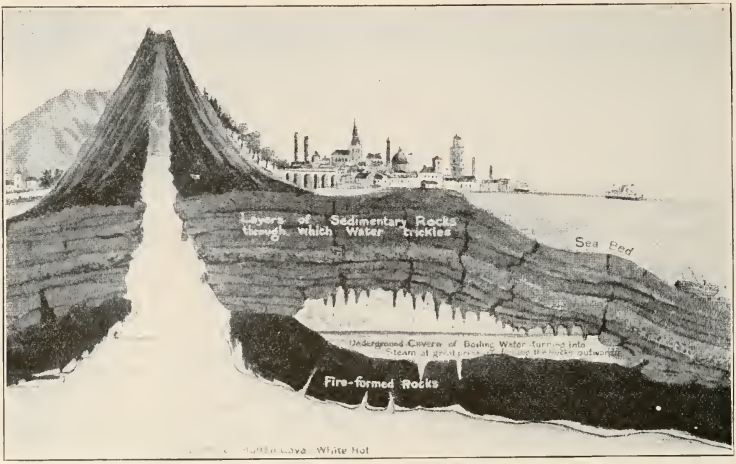
These rapid movements associated with earthquakes are very different from the slow earth movements, already mentioned. These quick movements may cause marked changes locally, on the earth's face in a few moments. On the other hand the slow movements go on steadily and with such slight changes, from year to year, that we do not notice them nor their effects. The sudden movements generally produce changes only over a relatively small area, while the slow movements affect large regions, even whole continents, or the slow movement may express itself in the form of mountain making and cause the uplift of such great systems as the Rocky Mountains or the Andes, which involve the crumpling of a third of the earth's circumference.

WHAT CAUSES THE FAULTS

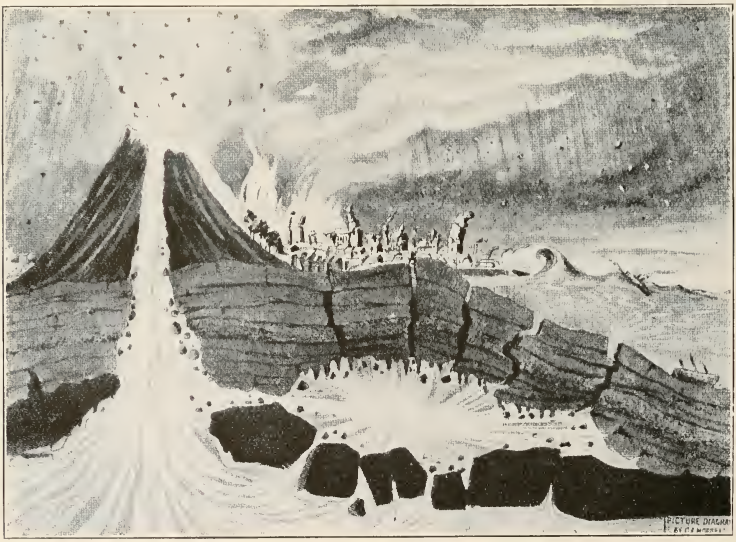
Though these two movements express themselves in such different ways, yet probably the same general underlying cause produces them both; this cause is, probably, the constant shrinking of the globe and the effort of the crust to adjust itself to the constantly withdrawing interior. It is this loss of heat which is the fundamental cause of all kinds of crust movements, however they may reveal themselves. The interior of the earth, though very hot, apparently, is not molten; it is solid and seems to be very rigid, as much so as if it were composed of steel. This hot interior, however, constantly radiates its heat out, through the crust, into space. As this heat is lost and the interior becomes cooler it is inevitable that it should shrink and become smaller. The outer part of the earth, which we call the crust, is supported by this interior and as it withdraws, the crust must follow it, for its support is taken away from it. The crust sinks down in its effort to follow the retreating interior; as the crust moves downward it must occupy a smaller space than it originally did. As the crust cannot be compressed very much, the only course open to it is to become wrinkled and to allow certain areas to be pushed up until the crust fits down on the interior compactly.

We have all noticed how an apple behaves when it is baked or allowed to dry, it loses water from the inside, which causes the interior to become smaller, the skin of the apple accommodates itself to the reduced inside and as a result it becomes much wrinkled. It is probable that mountain ranges, in part, are produced by this wrinkling, as well as other great features on the surface of the earth. All parts of the surface are in process of this shrinking, but the wrinkling of the crust does not appear everywhere, but only in those portions of the crust which are weakest. It is the weaker portions of the crust that give way and show folds, depressions and other evidences of change. These weaker parts of the crust are commonly near the oceans and it is in the neighborhood of sea coasts that this wrinkling takes place ordinarily.

HOW LAVA COMES OUT OF THE EARTH

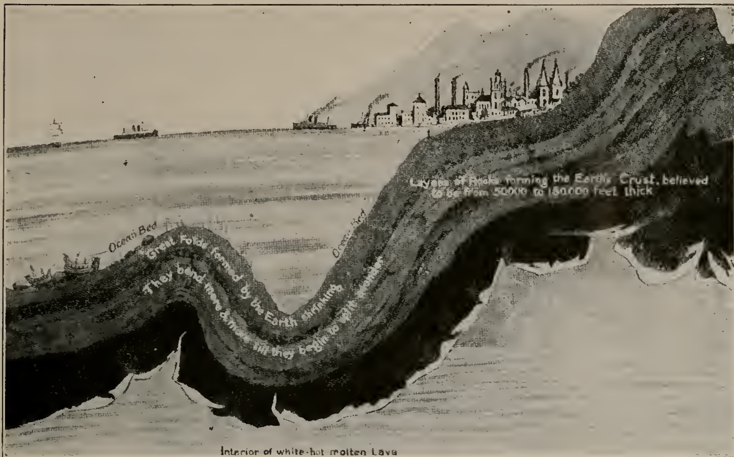


The pictures on this page show us at a glance one of the causes of volcanic eruptions and earthquakes. It is as though we were behind the scenes and could see the machinery by which Nature performs her most awful spectacle. This volcano is asleep, but processes are going on that will sooner or later cause a catastrophe.



Water is always trickling through the earth's crust from the surface, the heat inside the earth turns it into steam. At last the steam pressure becomes so great that there is a mighty explosion. The rocks are rent asunder, and the molten lava from the interior of the earth, with great force is hurled forth in a fiery stream. The rending of the rocks, too, causes an earthquake. This is probably how the eruption of Mount Pelee was caused.

THE SPLITTING OF THE EARTH'S CRUST



The interior of the earth is quite solid for the most part, but there are large pools of liquid lava, here and there. As the molten matter inside the earth gets cooler, the crust shrinks and crumples up, just as the peel of an orange shrivels when the orange gets dry. By this wrinkling the mountain ranges are formed, as shown here.

We usually think of the ground as being the one solid and firm thing that we know, until some terrible earthquake, like that at San Francisco or Messina, reminds us that even the ground is not stable. When the earth's crust at any point wrinkles so much that it is unable to bear the strain longer, the rocks split, as shown here, and the shock sends a shiver through the earth for hundreds of miles, causing buildings to shatter and fall.

It is true also that all portions of the crust do not sink with the same rapidity, some areas, apparently have always become depressed more rapidly than others, until now they are great permanent depressions, which we designate as ocean basins or sea basins, and occupied by great bodies of water. The continents have not gone down as rapidly and they stand up above the ocean, therefore, as protuberances, forming the familiar land masses and islands.

These great crustal changes have ever been going on, in some periods, apparently, more actively than at other times, but they are always taking place. They are going on day by day, now in our own lifetime, and for aught that we know with as much effectiveness as ever in the past. If there is any one idea, which we should bear in mind regarding the science of geology, it is that geology is not simply a record of past events and processes that have now come to an end, but that the forces which have formed the world, in the past, are still at work. We are living on the surface of the earth in a certain stage of its existence, just as creatures which lived on the earth millions of years ago, lived on the earth in another stage of its existence, but the activities of the globe are much the same now as they were then.

Portions of our country have been repeatedly covered by the ocean, sometimes, indeed it has extended quite across the continent. The crustal movements, which thus allowed the ocean to creep over the land, may come again and the sea may once more come up over the country. There is nothing permanent on the face of the earth, its expression is ever varying, and this is especially true of the boundaries between continents and oceans, they are, indeed, very evanescent features; the changes, which have gone on in ages past, are to continue their work.

Age of the earth

It should be remembered, too, that the earth, in all probability, is destined to exist for a great many millions of years, in the future, and that there will be ample time for many changes to be carried out.

Probably, men will be on the earth through all of these long years to come; the people, who live here in North America then, will live on the same continent as we do now, but it will have a different form, another outline and its surface will not be as it is now. It is perfectly possible that mountains may exist where now there are plains, and, on the contrary, the mountain ranges of the West may be worn down to inconsiderable hills and lowly ridges. When we look at a map of the world, we are looking at the arrangement of land and sea, as they happen to be at the present time, not as they were five million years ago, or as they are to be in the distant future.

Land and water areas interchange

There are many evidences that some of the continents have been much larger than they are now and that there were great prolongations of the continent, in some cases, which tied one continent to another. These old connections or "Land Bridges," as they are termed, were of great importance in enabling animals to pass from one continent to another. A map of Asia shows the Malay peninsula as such an arm stretching toward Australia, a great broken chain of islands connecting it with the great island continent.

Careful study of the region has convinced geologists that there was once, far in the geological past, practically continuous land connections between Australia and Asia. Over this land bridge migrated the kangaroo and other peculiar animals, now so characteristic of that island land. Shortly after their migration there, this land bridge was broken and the sea overwhelmed portions of it; this strange animal life was left shut up there, where it has remained ever since, unmolested by enemies, which have destroyed that kind of life elsewhere.

AMERICA AND EUROPE ONCE CONNECTED

Land bridges generally follow the borders of ocean basins, they do not extend across the deeper portions of the ocean; thus a land bridge has connected America and Europe, probably by way of Greenland and Iceland. It seems to be true, also, that if such a land connection is once established, although it may be overwhelmed by the ocean at some periods, yet it is likely to be re-established and appear again and again. The land bridge between Europe and America has been of that character, apparently; North America and Asia have been repeatedly connected by a land bridge across what is now the shallow Bering's Strait.

There are evidences, too, that during the Mesozoic era, a land bridge extended from South America to Antarctica, and that another bridge extended from Antarctica to Australia, so that animals might migrate from Australia into South America. These land connections are generally narrow, this is well shown in the case of the isthmus between North and South America.

It does not require a great amount of change to obliterate these narrow connections; through much of the middle portion of geological time and even later, the sea covered portions of Central America and the two continents of the Americas were separated. Geologists have discovered evidences of many land connections in different portions of the globe and existing in different geological periods.

In the course of these land movements it has happened, at times, that the continents, in certain portions, have been lifted high above sea level.

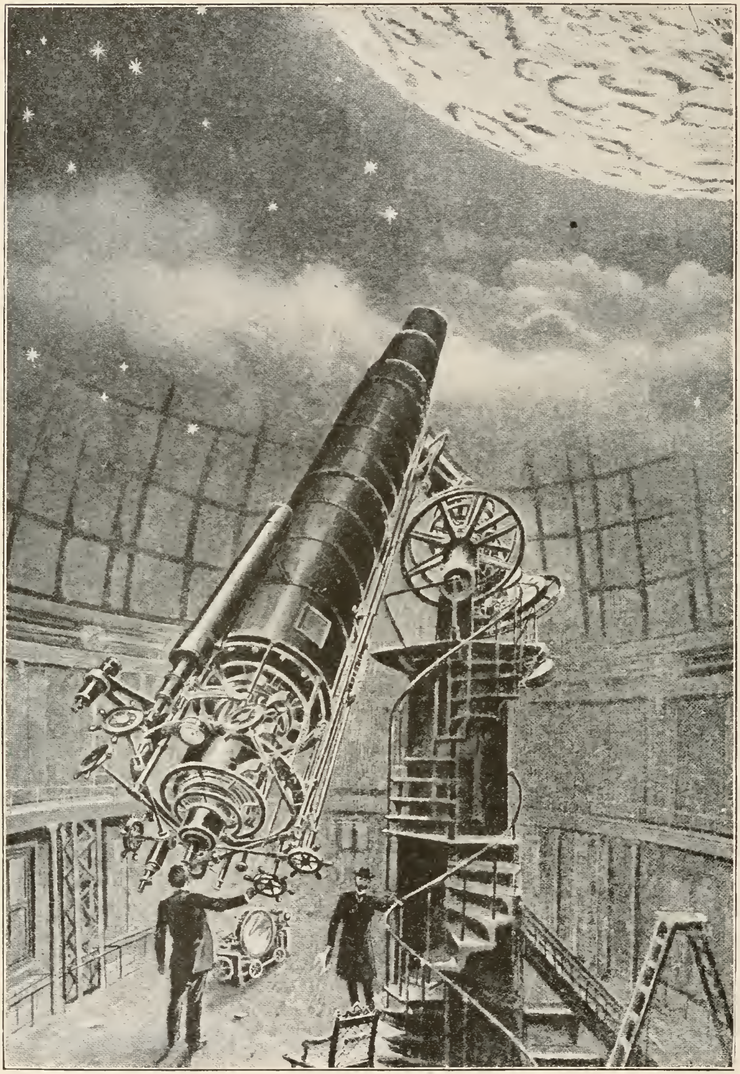
This was the case with the northern part of North America during the later Cenozoic era, just before the Great Ice Age. This remarkable elevation made a continuous continent, far toward the poles, joining Greenland to the mainland and obliterating Hudson Bay, probably. Such a great uplift had a marked influence on the climate and it was, doubtless, an indirect cause of the glacial period, which did so much to alter the face of nature in Canada and the northern United States.

THE LOST CONTINENT

From the time of ancient Greek writers there has been a story told about a lost Atlantis, a continent, which these early writers located in the west, and which was engulfed, supposedly, by the Atlantic ocean.

Stories of other lost continents are current, it may well be doubted whether there have been continents rising out of the deep ocean basins as they exist today. There have been the minor prolongations or land bridges already described, but no large, lost continents. It seems probable that the ocean basins have for ages been ocean basins and that the continents, likewise, have been land masses for long periods. It is true that the ocean has often invaded the land, seriously, but it should be remembered that the ocean, thus lying on the continents, is always quite shallow and has no such great depth as mid-ocean has.

Continents and deep sea basins do not change places with each other, in spite of the great earth movements, the ocean basins have too great a depth to pass into a continental stage. The average depth of the ocean is about 13,000 feet, nearly two and one-half miles, and this depth is so great it is not at all likely that continents have ever risen within such deep basins.



Of all the worlds in the sky, the moon is the nearest to us. It is only 240,000 miles away, and when we look at it through a huge telescope such as this, the moon seems to come down quite close and appear as near as does the small section of this picture. So large is the moon through a big telescope that we can study only a small part at a time, and we are able to make a more complete map of the moon than we can of some parts of the earth.

The earth we live on is only one of many worlds that fly through space. If we are to understand our own world, we must learn about the worlds in the skies, which we can see but cannot visit. In these pages we begin the study of astronomy, the science of the stars. Though men have been "star-gazing" for many ages, it was not until about three hundred years ago that astronomy really began as a true science—just about the time when all true science really began. A Danish monk and two Italians, one of whom was also a monk, were the real founders of our knowledge of the universe; and the greatest name after theirs is that of Isaac Newton. These men have taught us that our own earth, and the sun it moves round every year, are only a tiny part of the great universe, which contains millions of such suns and planets, in all stages of their history. And now, armed with the telescope, which brings the stars nearer to our sight, and the spectroscope which interprets the light of the stars, and the law of gravitation found by Newton, men are learning more and more about these worlds in the skies.

WORLDS IN THE SKIES

IT IS always true that if we are really to understand anything we must study not only the thing itself, but also what is around it. We cannot understand a part of any great whole, until we understand something, at least, of that whole. We cannot even understand ourselves unless we study the conditions of our lives, our parents and schools, what we read, the air we breathe, the things we hear people say and so on. And in the case of the earth we can never hope to understand it unless we study the great world of which it is really a very tiny part. This study is known as astronomy—the word means the law of the stars—and it is in many ways, though not in all, the most marvelous of all the sciences.

Astronomy is probably the oldest of the sciences. Men were always interested in the weather, in changes of climate, and in the sun, which plainly has so much to do with what happens in the sky around us. The sun and moon were closely watched by men, probably before anything else at all. Also the stars are far more brilliant when they are seen through the clear air of warmer countries than ours, such as Arabia and Egypt; and as they seem to be fixed they can guide men on the sea and on land. Thus, astronomy was useful from the first, as it is useful today, though most of us have no idea how useful it is. So it comes about that we find proof of astronomical knowledge long ages ago, even thousands of years before the birth of Christ. This is specially true of the East, more especially of Western Asia and Egypt.

The names of most of the sciences, we know, end in ology, and we might expect the name of the science of the stars—using the word stars to include all the bright objects in the heavens—to be astrology.

THE ALCHEMISTS AND ASTROLOGERS WHO BEGAN THE STUDY OF THE EARTH

We use the word astronomy, however, to distinguish this real science from an unreal science which came before it, and which was called astrology. If we turn to the great science of chemistry we find exactly the same thing. Before what we now call chemistry came into existence there was an unreal science called alchemy—which is really the same word. The alchemists were searching for the philosopher's stone that was to turn everything into gold, and for the elixir of life that was to turn or keep everybody young. The alchemists were wrong in looking for these things, and they were wrong practically always in the way in which they interpreted the results of their experiments. But we could not have modern chemistry if there had been no alchemists. They were eager and patient men who made numberless experiments and noted numberless facts. They laid the foundation of chemistry, and though they were wrong in their objects, and wrong in their attempts to understand what they noticed, yet we profit in a thousand ways by their discoveries today.

And just as every modern chemist is indebted to the alchemists, so every modern astronomer is indebted to the astrologers. We could not have had our modern astronomy but for them. They, too, like the alchemists, were eager and patient men, and they observed thousands of facts about the heavenly bodies.

THE STRANGE THINGS MEN THOUGHT LONG AGO ABOUT THE STARS

They were wrong in the way in which they interpreted those facts, but a fact is a fact forever, and since it is part of truth, is a part of true science; nor does it matter, in the long run, that the man who observed it misunderstood it—whether sincerely or dishonestly. We find in the early history of every race and nation that we can trace a kind of astrology—that is to say, a study of the stars in the belief that they controlled the fates of men. Egypt and Persia, Arabia and Greece, the Chinese and the Hindoos all contributed to astrology, and so when civilization began in Europe it took over these ideas from the first. They flourished for thousands of years, and even today we can buy almanacs which pretend to predict what will happen on the earth by studying the stars. The astrologers took those of the planets that they knew, and connected human characters with them. Venus had something to do with love, they thought; Mars with war, and so on. They divided up the sky into various parts, and supposed that when a certain planet entered a certain part of the sky corresponding results would occur for human beings, especially for anyone who was born just at the moment when that particular part of the sky happened to be going to rise above the horizon.

Of all the astronomical discoveries, one stands out as that which, beyond all others, destroyed astrology, and that was the discovery by Copernicus that the sun and not the earth is the center of the solar system. We must remember, too, that in this case, as in every other, people will believe the false unless they know the true. So in our own time and in the future, wherever there are people who do not know anything about astronomy, they will believe what astrologers tell them.

We have already learned that astronomy was useful from the first, and we should particularly notice the difference between the real use of real knowledge and the sham use of sham knowledge. The astrologists declared that the study of the stars was useful because it enabled them to predict what would happen to men—which is a thing that men always want to know.

HOW THE STARS GUIDED THE TRAVELER IN THE EARLY DAYS OF THE WORLD

Sometimes they happened to be right, as anyone may happen to be who makes a prophecy, especially if he takes care that it is a likely one. But usually they were wrong, and so they were not merely useless, but worse than useless. Yet all through the time of astrology there was a certain amount of real astronomy known, and this was useful then as it is now. Especially was it so because observation of the position of the stars guided travelers, whether on the sea or on the land. Traveling has always been important, but there were no good maps in those days, and the compass was only known in China. The skies are almost always bright, however, in Egypt and Arabia and Greece, and so the stars could always be seen at night to help the traveler to his goal. Every ship that crosses the sea is indebted to astronomy today, and always will be.

But the thing we should notice particularly is the difference between the sham knowledge and the real knowledge—the worse than useless and the very useful. They both depended upon facts and upon the same facts—that such and such stars could be seen at such and such places at such and such times. But the sham knowledge with its bad consequences depended upon a false interpretation of true facts, while the useful knowledge depended upon a true interpretation of the true facts.

How mankind was cheated and led astray for thousands of years

The great lesson which we have to learn from this applies to all knowledge of every kind; whether we are studying stars or disease or the rocks or history or anything else, there are always two things which it is our business to find out. First come the facts, and then comes the meaning of the facts. We must have the facts first, and we get these either by simply observing—as when men look at the stars, or by making experiments—as we do in chemistry. The facts are facts whether we understand them or not, and in any case we must have the facts first. After that comes the business of trying to understand what the facts mean, and if you do not know what they mean it is much better to say so and to go on looking for more facts, rather than to pretend you know what they mean.

We thank and praise the astrologers for finding many facts, but we cannot thank them, and are, indeed, bound to blame them, because they pretended to understand them when they did not, and because for thousands of years they cheated mankind with their pretended explanations. The astronomers of today ask money from mankind as the astrologers did, but they do not ask it in return for sham prophecies as to what will happen to you and me, but they ask it for telescopes and observatories, so that they may learn more about the wonderful world in which we live.

Brave men who suffered for believing what men now believe

Our more definite knowledge of the history of real star-science begins with the Greeks, and we know that some Greek astronomers had discovered the true shape of the earth, the fact of its spinning and its revolution round the sun. Then these truths were denied and despised, and for many centuries men went back to the old view that the earth is motionless and flat, and that the sun goes round it, as it certainly seems to do.

But in the sixteenth century there arose a great man, a monk, called Nicolas Koppernik, of Denmark, whose name we now know in its Latin form of Copernicus, and he proved again the truth that had been lost for nearly 2000 years, that the earth goes round the sun, and that the other planets, such as Mars and Venus and Jupiter and Saturn, do so too.

His great follower, the Italian, Galileo, invented the telescope. With it he completed the proof of the view held by Copernicus. He found that Venus has phases like the moon, showing that it goes round the sun in a path *inside the path of the earth*, and he found four of Jupiter's moons, showing that it was like the earth, which also has a moon. And so we learned to think of the sun and its family, the *solar system*, about which we have already read a little in this book. Galileo was over and over again stopped and silenced by the Inquisition. He was made, under threat of torture or death, to declare that his discoveries were false. He was forbidden to write any more, and the poor old man, alone in the world—for he had lost his beloved daughter—died miserable, alone and despised. But his glorious name will be revered and honored by all men as long as mankind endures.

About the same time there lived a man, also a monk, like Copernicus, of Denmark, who saw farther and deeper than either Copernicus or Galileo, though he was not an actual discoverer with his own eyes. He was an Italian, named Giordano Bruno; and if you think of him as if his name were George Brown, you will realize that anyone, anywhere at any time, may make his name immortal. Bruno or, Mr. Brown, as we should call him now, was the first man to realize the true nature of the mighty universe in which we live, and so his work is of lasting interest to all men.

We saw what Galileo's earthly reward was; but Galileo sacrificed himself at least in some degree, by denying what he knew to be true; and so we cannot say of him that he was so completely a martyr for the truth as he might have been. *Martyr* really means *witness*, but we use the word to mean a witness who pays for his witness by his life. Bruno was attacked, as Galileo was, soon afterwards. He, too, recanted, or took back what he had said, for a time; but afterwards something within him made him ashamed of doing so. He boldly declared again what he believed, which is what we all believe now; and the Inquisition burned him in the Campo di Fiora—the Field of Flowers—in Rome, in the year 1600, on a spot where, three hundred years afterwards, in 1900, a statue was erected to his immortal memory.

HOW ISAAC NEWTON CARRIED FORWARD THE TRUTH THAT BRUNO DIED FOR

Before we learn what Bruno taught the world, there is one other name which we must learn in the history of astronomy. It is that of an Englishman, Isaac Newton, who discovered the law of gravitation, by which the universe is balanced. This he did when he was 23 years old. When he published his discovery people said that he was wicked, and was trying to take away from the glory of God; but now all men honor him, and see that the more we learn about Nature the more we learn about the wonder and power of its Great Author.

THE FIRST MAN TO UNDERSTAND THAT ALL THE STARS ARE SUNS

When Bruno read and thought over the work of Copernicus, there came into his deep mind the true view of what our universe really is. The first great truth he saw was that the sun—our sun—must really be one of the stars; and with that great idea in his mind he began to think of the other stars. So he saw that *if the sun is a star the stars are suns.*

Consider how tremendous is the meaning of that sentence, and especially of its conclusion: *the stars are suns.* Men had thought of the earth as the center of all things, the sun as its attendant, daily moving round it, and the stars as little points of light—mere trifles, giving no useful light, and meaning nothing, unless that somebody would meet with an accident in a certain year, or that someone else would win a victory, if certain stars could be seen at certain times. And then Bruno came and taught that these little points of light were suns, like our own, perhaps vastly bigger and more important, and that probably there were planets circling round them with living creatures, perhaps as intelligent as men, or even more intelligent than men, upon them. This is the most humbling discovery to the pride of human beings that men have ever made, and it is also the grandest. Men saw only one side of it then, and perhaps we should not wonder that they burned Bruno.

THE EARTH IS AS A GRAIN OF DUST IN A MIGHTY MASS OF WORLDS

The universe, then, consists chiefly of a vast multitude of stars, of which we can reckon not less than one hundred millions already. Of these our sun is just one, and certainly neither the biggest nor the brightest, though infinitely more important to us than all the others put together. Around any number of these stars there may be planets, perhaps with moons, circling as we do round our particular sun. And the whole of our earth is but as a grain of dust compared with the whole mighty mass of worlds which we can see on any fine night from the earth's surface.

As to the size of the visible universe, we learn similar lessons. The earth is quite small, compared with Jupiter, the giant planet, and Jupiter is small compared with the sun. But if the whole space surrounded by the path of the outermost planet, Neptune, from the sun outwards, were one solid mass, a mighty ball in which sun and earth and Jupiter and all would be lost like drops of water in a lake—even then this great globe would be nothing in size compared with many of the objects we see in the sky, and the distance from boundary to boundary of it would be nothing compared with the distance from it to the nearest star.

In looking at the sky, then, we must always remember the meaning of these tremendous distances between stars and stars, and we must not be deceived, as so many men have been deceived, by the apparently *equal* distance of a planet and a star beside it.

THE LIGHT THAT HAS BEEN TRAVELING SINCE THE SPANISH ARMADA WAS DESTROYED.

It is not merely that the planets—which belong to our little system—are nearer than the stars, but that, compared with the stars, they are at our very doors, while the stars are almost infinitely far away. Something happened to a star which we noticed a few years ago, and much attention was paid to it. Yet we reckon that whatever it was really happened before the Pilgrims landed on Plymouth Rock, and the light that then left the star reached our eyes only a few years ago.

Thus to the eye of the astronomer the bright points in the sky are of two utterly different kinds. All but seven of them—among these scores of millions—are suns, vastly far away, and many of them vastly bigger than our sun.

But seven of these bright points, together with the sun and the moon, and the moons of the other planets that have moons, and a number of very tiny planets, perhaps as small as an American county, that can only be seen through a telescope, are parts of the solar system; they belong to us, they are close neighbors of ours, and have nothing to do with any of the stars among which they seem to lie.

Now let us make a list of the various things that make up the universe, and that astronomers study. First, we shall note down the things that make up *our* system; we shall think of it as a kind of sample of what makes up millions of other systems in the sky—only that they are so far away that we can only see the suns—or stars—of those systems.

THE THINGS THAT MAKE UP OUR PART OF THE UNIVERSE, THE SOLAR SYSTEM

Our system consists of the sun; the eight large planets of which our earth is one; the moons of those planets; the minor or lesser planets, which all revolve round the sun in a sort of heap, in a path outside the path of Mars and inside the path of Jupiter; a large number of tiny things like stones and pebbles and pieces of rock, much too small for us to see, except when they are caught in our atmosphere and made bright, when we call them meteorites, or "shooting stars"; and a few curious things called comets, which also move round the sun and belong to our system. We ought really to learn this list. It is much easier to learn than a list of dead kings, most of whom could not read, and it is quite as important. The pebbles, the comets, and the minor planets are the things you are likeliest to forget. The names of the major planets are given on page 18, and we certainly should learn them and their order outwards from the sun.

Again we must remind ourselves that several of these things may be seen in the sky, either with the naked eye or through a telescope, just as if they were stars, but they are really just about as far from the stars as we are, and belong to us. When astronomers discover a new minor planet —and there are hundreds of them known—they cannot tell whether they are dealing with a tiny little planet, perhaps smaller than Rhode Island, or a star that may be vastly bigger than the sun, until they find that it moves or wanders among the stars, and so is a planet, or *wanderer*.

THE GREAT DIFFICULTY OF UNDERSTANDING THINGS SO FAR AWAY

The difficulty people have in learning how utterly different Venus is from a star like Sirius is a difficulty that even astronomers have to reckon with, so great is the influence of distance in deceiving us as to the comparative importance of things. We must learn from astronomy that a very tiny thing may be taken for a very big thing, if only it happens to be near enough.

We can never know any other of the millions of solar systems as we know our own, but whenever we look at a star we must think of it as Bruno thought of it, and remember that it is probably *the sun* to other planets, and perhaps to intelligent beings not very unlike ourselves. But in the universe, outside the little limits of our solar system, there are many other things beside stars, and we know what these various things are. Then, when we have got firm hold of the right idea of the universe and what it is made of, we shall be ready to study some of these wonderful things more closely.

We discover in the heavens, apart from our small system, many bright stars. Without seeing them, but in other ways, such as by noticing how they disturb the bright stars, we discover also many *dark* stars; stars that have grown cold and "gone out."

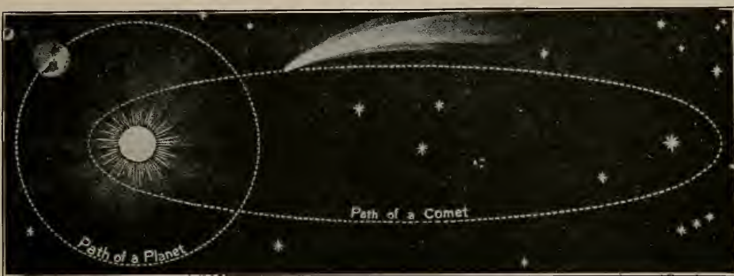
THE COUNTLESS NUMBER OF STARS IN THE SKY AND THEIR MANY KINDS

A well-known astronomer, Sir Robert Ball, has said that to look at the bright stars—the stars we can see —and say, "These are all the stars," would be like counting all the *red-hot* horse-shoes in a country and saying, "These are all the horse-shoes." The bright stars are probably very few compared with the dark ones. Bright stars and dark are of many different kinds, but we shall read about them later. Here we must remember both of them as helping to make up the mighty population of the skies. And after them we must put down the names of the *nebulæ*. Nebula means *cloud*, and *nebulæ* means *clouds*. The nebulæ are things which *look* like tiny clouds among the stars. We have already learned that the solar system was made from a nebula; and we believe that all the stars, and the systems of which they are the suns, were also made from nebulæ.

There are many stars in the heavens which seem to be still only half-made—still more "star-mist" than star—and these we call nebulous stars. There is a great nebula in Orion, in which six stars can be seen to have already condensed. We can see Orion for ourselves in the early winter evenings in the south. To our naked eyes the nebula looks like a star—the middle star of three forming the dagger of the huntsman which the ancients thought Orion looked like.

It is almost certain that there are dark nebulæ as well as bright ones, and that we must therefore remember both kinds as we remember both kinds of stars.

THE LONG AND LONELY JOURNEY OF A COMET. WITH ITS TAIL MILLIONS OF MILES LONG



This picture shows the path of a comet round the sun. At one time the comet comes quite close to the sun and just misses running into it; then passing round the sun, it travels far beyond all the planets, millions of miles into space, until it comes to the sun again. The circle shows how the earth goes round the sun, and it is when a comet comes close to the earth's path that we see it.

THE MYSTERIOUS JOURNEY OF A COMET THROUGH SPACE

There are also in the heavens many comets besides those that belong to the solar system, and go round the sun as regularly as the earth does. A comet is quite a small thing, really, and requires to be near to be seen. Even the comets that belong to the solar system can only be seen occasionally when they come comparatively near to the sun. The comets in outer space cannot be seen. But we know that they are there, since some of them occasionally visit us. After rushing through space for the vast distances that stretch between star and star, they may visit *our* star, the sun, and after rushing round it may fly away again into space and be seen no more—by us. Astronomers know that these comets do not belong to the solar system, and will never return, as the paths they pursue are not *closed* paths, like a circle ◯ or an ellipse ⬭, but open ones, like this ⊃, which carry the comet through space, perhaps never visiting the same star twice, until its history ends in its breaking up into little parts like the stones we call meteorites.

The most brilliant of all comets in the memory of living men was that of 1858, known by the name of its discoverer, Donati. Its tail was over fifty million miles in length

THE MOON, THE LAMP OF NIGHT

FOR many millions of years the earth has been attended by a satellite—which means attendant—called the moon. In all ages men have admired the moon, and in the history of almost all nations there are records that the moon has actually been worshiped. It is, of course, the most brilliant body in the whole heavens, after the sun, so far as our view of things is concerned; and, just as the sun is the king of day, so the moon is the queen of night, and on account of its beauty has been celebrated by thousands of poets. The whiteness of the moon's light has always been for poets an emblem of purity, though this light, as we know, does not originate in the moon, but is merely reflected sunlight.

The time has gone when men thought that everything in the world existed only for their use, nor do we now credit the moon with the power of causing lunacy, which really means moon-acy. But we know that the moon has very important influences upon the earth. The most obvious of these influences is the light which the moon sends us, which at night may sometimes be quite useful. We have already seen how little of the sun's light the earth catches, and the moon, being smaller than the earth, catches much less. It has been estimated that it would require 600,000 full moons, all shining together, to light the earth as brilliantly as the sun lights it now.

The sun is always shining, and the side of the moon which is exposed to it is always lighted by it, except for a few minutes now and again, when the earth gets between the sun and the moon. The proof of the fact that the moon gives out no light of its own is to be found in the changes that the moon goes through every month. These changes, which are shown in the illustration, can have only one meaning—which is, that all the light we see the moon by is reflected sunlight. The moon is practically a sphere and therefore any source of light like the sun can light up only one half at any time; and if the sun's light is falling on the half which is curved away from us, then we see no moon at all.

The only exception to this is that sometimes we can see what people call "the old moon in the young moon's arms." We see, perhaps, a beautiful bright crescent, and then the rest of the moon very faintly shown. The bright crescent we see by reflected sunlight, and the rest of the moon's face by reflected earth-light. This is one of the facts which prove that the earth, seen from somewhere else, would look bright. It reflects sunlight enough, indeed, to light up the face of the moon at times sufficiently for us to see it by.

The brightness of the moon depends on its nearness. In all the heavens there are only a very few bodies that we can see which are smaller than the moon, but the moon has the great advantage of being very much nearer us than anything else. Its distance from the earth is only about 240,000 miles—less than ten times the distance round the earth. Compared with the distance of the sun or of Mars, this is, of course, very small indeed. It gives us the great advantage that we can study the moon with our telescopes more closely than any other body in the heavens.

WHY THE MOON COOLED DOWN AND DIED SO QUICKLY

The moon, however, is very tiny and the whole face of it, which we see, is only about twice the size of Europe. If you look at Europe on the map of the earth, you will see that it does not amount to much. The distance through the moon, or its diameter, is only a little more than a quarter that of the earth, and "if the earth were cut into fifty pieces, all equally large, then one of these pieces rolled into a globe would equal the size of the moon." But the surface of the moon is about one-thirteenth that of the earth. These figures are extremely important and interesting. They show us that when the moon is compared with the earth, it has a far bigger surface in proportion to its size. It is only one-fiftieth of the size, but instead of having a surface only one-fiftieth the size of the earth's its surface is one-thirteenth that of the earth. That is why the moon has cooled so very much more quickly than the earth has done, and this rapid cooling of the moon accounts for two things: first, its cold and lifeless state today; and second, the character of the moon's surface, which shows that its life, so to speak, was "a short and merry one." The cooling crust of the moon shrank down upon its interior so quickly that the most violent things happened, the marks of which remain long ages afterwards on the surface of the moon for us to study.

THE SIDE OF THE MOON THAT MEN HAVE NEVER SEEN

The fact that the distance across the moon looks to us always about the same indicates that the moon's distance from the earth varies very little, and that is so. The reason is, of course, that the moon travels round the earth in a path which is very nearly, but not quite, a circle. It moves once round the earth in about twenty-seven days and a third. This time makes the real month, which we call the lunar month. There are twelve months in the year according to the calendar, but that has only been made so for convenience. Really there are thirteen and a little bit more; in other words, while the earth goes round the sun once, the moon goes round the earth a little more than thirteen times.

But, as the moon goes round the earth, we find that it keeps the same side towards us. Indeed, we have never seen, and never can see, more than the same one half of the moon's surface, or just a trifle more than half. The reason is that the moon is slowly spinning upon itself as it moves round the earth, and it makes one complete spin on its axis in just the same time as it takes to go once round the earth. In other words, the moon's 24-hour day is a month long.

Anyone living upon the moon, then, would have day and night as we have day and night upon the earth, and for the same reason—because the moon is spinning. But, as the moon's spin is very slow, the bright part of his day would last about two weeks, and the dark part of it, corresponding to our night, would last another two weeks.

A WORLD THAT WE KNOW BETTER THAN WE KNOW AFRICA

Of course, we should like to see the other side of the moon, but we may be quite sure that if we could it would be very much the same as the side we can see. We have now mapped out the visible half of the moon very carefully with drawings and photographs. As Sir Robert Ball has said, "astronomers know the surface of the moon better than geographers know the interior of Africa. Every spot on the face of the moon which is as large as an English parish has been mapped, and all the more important objects have been named." This, we must remember, however, applies only to one-half of the moon's surface. Of the other we know nothing. When we look at a map of the moon, or when we look at the moon through a telescope, we do not see at all anything like the face we all know so well, but we see at once what it was that made the appearance of a face.

The moon's surface is richly covered with markings, the largest of which are great dark spaces, which are the markings we see with our naked eyes. These spaces, though they contain no water, were called "seas" by the old astronomers. We also see great ridges, which are mountain ranges, and large rings, which are thought to be the remains of volcanoes.

There can be no question that many of the things we see project above the surface of the moon, and that they are lighted from some source outside them, for we can see their great shadows. When the moon is quite full, and the sun is

A PHOTOGRAPH OF THE MOON: A DEAD WORLD LIT UP BY THE SUN

This is a picture-map of the moon, which is really a dead world, as the earth would be if there were not one living thing upon it. The moon travels round the earth as the earth travels round the sun. It is not light in itself; what we see is the light of the sun upon it, as we see the light of a candle thrown upon a wall. We see really one-half of an enormous globe, like a small earth, lit up in the sunshine, spinning in space like a fireball, yet weighing millions of tons.

striking directly upon it as we see it, these shadows are absent, and, indeed, though the moonis then beautiful to the naked eye, the astronomer cannot learn from it nearly so much as he can at other times. If we want to see a lunar mountain at its best, we must watch it when it is not far from the edge between light and darkness. The sun's rays are then falling upon it slantwise, and we can see its form, the shadows it throws, and learn from them the size of it.

The shadows thrown by the mountains of the moon are extremely dense and sharp. The reason is that the moon has no air. The shadows thrown on the earth are neither so black nor so sharp as they would be if there were no air, for the air spreads the light about, and throws a certain amount even upon the blackest part of the blackest shadow. Now, it is not difficult in the case of the earth to find out how high a thing is if we can measure the length of its shadow. We should do this at noonday, when the sun is highest in the sky, and then, if we know how high the sun was on the day in question, we can calculate from the length of the shadow what the height of the object is. Indeed, if, in our latitude, we make the measurement on certain days in the year, the length of the shadow is the same as the height of the thing we are measuring. It is not a very difficult matter to find out the number of miles that a shadow on the moon extends, and we can also find out how high the sun would appear to anyone looking at it from that part of the moon. So we can measure the height of mountain peaks and crater edges in the moon. We find craters fifty, sixty, and more miles wide. Some of these have walls of the most tremendous height—10,000 feet, for instance. In other places, instead of a deep crater, we find a great plain, perhaps with a mountain peak in its center, perhaps not. One of the most splendid of these craters is named after Copernicus, and many other astronomers have had their names given to the larger craters that mark the surface of the moon.

THINGS THAT HAPPENED BEFORE THERE WERE HUMAN BEINGS ON THE EARTH

According to many astronomers, there are still occasional traces of things going on upon the moon. For instance, we believe that a small crater has been found that was not there before. However, even if there were no doubt that small changes still occur on the surface of the moon. we are certain that nothing which now occurs there can compare for a moment with the tremendous events which created the moon's surface as we now see it. So far as we can judge, these events must have occurred not merely long before there were any human beings upon the earth to witness them, but at a time when the earth was so hot that no life of any kind upon its surface had yet become possible.

In any case, the facts of the moon's surface clearly show quite what we should expect when we remember how quickly a small body cools compared with a large one. There is one crater upon the moon which is nearly eighty miles across, and the moon's craters and mountains are not to be found here and there merely, but cover it almost everywhere. Indeed, we require some other explanation of the reason why such tremendous heapings up of matter have been possible upon the moon, and that explanation is again to be found in the moon's small size.

A MAN ON THE MOON COULD JUMP ACROSS THE STREET

The force of gravitation on the moon's surface is very different from the force of gravitation on the earth's surface. It is only one-sixth as great.

THE EARTH AS VIEWED FROM THE MOON

This picture shows us what the earth would look like if we could see it from the moon. The light of the sun falling upon the earth must make it shine like the moon when seen, if it is seen from the other planets. No beings dependent upon air for their life could live on the moon for the moon is an airless world. People on the moon could not speak because sound does not exist without air; the largest cannon ball that could be fired if it could be made to reach the moon, would fall like a pin upon velvet. The moon might be filled with lovely flowers but they would give off no perfume, birds might sing from every branch, but not a note would be heard. For the moon is a silent world where sound and speech and smell cannot exist.

A man who on the earth can jump six feet high, as some can, could jump thirty-six feet high on the moon. This means that the explosive force of the volcanoes on the moon, hurling upwards all the substances which reached them from the interior of the moon, would be resisted by a feebler force of gravitation, so much less than we are familiar with on the earth that we can begin to understand how some of the great features of the moon's surface can have been formed.

WHY THERE ARE NO SUCH CHANGES ON THE MOON AS ON THE EARTH

Air and water, as we know, are always smoothing away the prominences on the earth, rubbing them down and rounding their edges; but when a great mass of lava was thrown up by a volcano on the moon, and hardened as it cooled, it took a shape which ages could not change, for there was nothing to cause the change. There is only one fact about the moon which can contribute much to any changes upon its surface now. As the moon has no blanket of air, it is very much exposed to the rays of the sun. During the moon's day which is as long as 27 of our days, the surface must become intensely hot, but during the moon's night, which is as long as 27 of our nights, there is nothing to keep in the heat which it has received during the day, so that the heat is radiated freely, and the moon must become colder than any part of the earth ever is. So, the surface of the moon must shrink very much with cold and expand with heat each night and day.

THE PATH OF THE MOON ROUND THE EARTH

That is all we can say now about this very difficult but very interesting question. If it were true that this was the origin of the moon, we should expect to find the moon spinning upon itself and revolving round the earth, in the same direction as the earth spins on its axis and revolves round the sun; and so we do. But the path of the moon round the earth is not quite on the same level, or in the same plane, as astronomers say, as the path of the earth round the sun. In a picture on a flat page—like, for instance, one of the pictures of this part—it looks as if the moon were traveling round the earth on the same level as the earth is traveling round the sun. If this were so, of course we could not see a full moon, for then the earth would be in the way of the sun's light, and instead of a full moon we should have an eclipse of the moon every month. Also the moon would eclipse the sun every month. But if we think of the moon's path round the earth as being tilted a little at an angle to the earth's path round the sun, we shall understand how it is that we are able to see a full moon, and we shall also understand that, at certain regular intervals, when the path in which the moon moves crosses the path in which the earth moves, there may be an eclipse.

WHAT THE EARTH WOULD LOOK LIKE TO A MAN ON THE MOON

If intelligent beings lived upon the moon, our earth would appear to them a most magnificent object, looking in the sky many times larger than the moon does to us, equally bright as a whole, but often hidden partly by clouds, as the moon never is. This large earth would eclipse the sun, but the size of the earth as seen from the the moon would be very much larger than that of the sun, and so an eclipse of the sun by the earth, as seen from the moon, would blot out not only the body of the sun, but also its prominences and the corona, and would only leave all round a faint glow of light.

STARS AND CONSTELLATIONS

THE beginning of the study of the stars was made very long ago, ages even before the invention of the telescope or any kind of instrument, when men had only a pair of eyes and a good brain behind them. The Assyrians and Egyptians, the Chaldeans and the Greeks, had no telescopes and few observatories, but they learned practically everything that was known about the stars until almost our own times. For, after all, anyone with eyes, who cares to use his eyes, can study the stars and learn a great deal about them.

The first thing men learned was that a few of the bright points in the sky, like stars, move about or wander among the other stars. These wanderers, or planets, we now understand; and we keep the name "stars" for all the rest, which for many ages were called the *fixed* stars, in order to distinguish them from the *wandering* stars. There are good reasons why we should drop the word *fixed*. It is not necessary, as we can call the wandering stars *planets*, and not stars at all; and it is not true, for we know that many of the "fixed" stars move, and we have reason to believe that they are all of them moving.

If we watch these stars, however, every clear night for the whole span of our lives, we notice no movement; and this is true of most of them, even though they are watched for generations or centuries. They seem to keep the same positions compared with one another, though the whole sky seems to have moved at different times of the year or at different times of the night. The winter sky, for instance, seen from our part of the world, is much more interesting than the summer sky.

Thus it happens that men's eyes naturally came to group the stars together, and these groups, we know, are called constellations. From night to night, or year to year, the stars making up a constellation remain in the same positions beside one another; and so, if six form a sort of coronet, men call them the crown, and so on. The proper name for these six is the Northern Crown or Corona Borealis, and you can find it in the accompanying picture—or, much better, in the sky. Borealis is derived from Boreas, the god who was supposed to blow the north wind. But it is most important for us to understand now what could not be understood long ago.

HOW MEN THOUGHT THEY WERE LIVING IN A BALL, WITH THE STARS STUCK ON IT

When we look at the sky it seems to be a sort of dome or bowl upside down—someone has called it "that inverted bowl we call the sky"—with all the stars stuck on it, at the same level or distance from our eyes; so that what we *see* as a group of stars would really *be* a group of stars, or a constellation. And astronomers actually thought that the stars were attached to a mighty sphere, inside of which we were, and that the movements of the sky as a whole were due to this great sphere or hollow ball moving round and carrying all the stars together with it. The planets, moving separately, had to have other supposed spheres or bowls invented for them, and we may guess how complicated and impossible the whole thing grew, for it was wrong from the first. It is as if you looked across your room and thought that everything was on the same level—at the same distance from your eye. A funny notion you would have of what your room really is! But actually you see the room *in perspective*, and you know that things which lie side by side in your field of view may be, one quite near and the other at the far end of the room.

THE IMMENSE DEPTHS IN THE SKY THAT WE CANNOT REALIZE

Unfortunately, we cannot see the sky in perspective. If we could—if we could get any notion at all with our eyes of the *depths* of space—much more than half of all the mistakes of astronomers could never have been made. Any boy could have corrected them the first time he was out on a fine night.

Nevertheless, of course we must learn the principal constellations, for they are the landmarks of the sky—or skymarks, if you like—and they are always referred to when we want to say where to find a comet or a planet at any particular time. And here we may learn a very interesting thing. The "fixed" stars are not fixed, and therefore, as they move, the constellations ought to change. And so they do. The first astonishing fact about these changes is that, on the whole, they are so slight. We have names and records going back for ages; but, in general, the face of the sky is very much what it was when the study of the stars began.

THE CHANGES THAT TAKE PLACE SO FAR AWAY THAT WE CANNOT SEE THEM

Yet we now know that many of these stars are moving perhaps ten or even a hundred miles every second. This can only mean that the distances of the stars are enormous; for, of course, the nearer things are to our eyes, the greater is the visible effect of their movement, and vice versâ.

But the second fact is that, though the changes seem so small, considering how long the stars have been watched by mankind, yet there are changes. For one thing, we know certain constellations, or groups of stars, which the ancients did not name, and which have received names near our own time. Knowing how carefully the old astronomers watched, and how ready they were to give names, we may reasonably believe that the reason why they took no notice of these "new" constellations, as they are called, is that they were not there to be seen. The stars making them have moved in the sky, and the "new" constellations are therefore really new in the sense that, a few thousand years ago, the stars making them did not look like a group of stars, or a constellation, to the eye, as they do now.

Some of the names given to the constellations, suggesting that they look like things we know, may seem very absurd. Here, too, the fact that the stars are not really fixed may help to explain. It may be that, when the name was given, the stars were in positions that made the constellations look more like their names than some of them do now.

THE NORTHERN AND THE SOUTHERN HALVES OF THE SKY

If we consider how the earth turns in space, we shall understand that only the northern half or so of the sky can ever be seen from most of the United States. As it happens, this includes the more interesting and wonderful stars, though perhaps we may think so only because the great astronomers have all lived on the northern half of the earth, and there is scarcely more than one first-class observatory—that of Cape Colony—on the southern half of the earth yet; so that we really do not know nearly so much as we should about the southern sky.

But everyone who lives in our part of the world should know, at any rate; a few of the finest constellations and stars that can be seen from here without the use of any machinery except that by which the Greeks made such great discoveries in astronomy—a pair of eyes and a mind. The pictures show us what we really ought to know, and here are mentioned the principal stars that are shown. But the pictures do not show one thing which would interfere with their clearness, and that is the northern half of the Milky Way, the great belt of stars which runs right across the entire sky, all the way round.

THE QUEER NAMES THE ANCIENT ASTRONOMERS GAVE TO THE STARS

We all should know the seven stars that form the tail and part of the body of the Great Bear. These seven stars are also called the Big Dipper. When we see them we can always find the Pole Star, by following up the line made by the "pointers," Dubhe and Merak. Look straight at the Pole Star and that is the *north*. Now go back to the Great Bear, and follow the course of his tail downwards and backwards, until you come to the magnificent star Arcturus. This is one of the brightest stars, which are called "first magnitude" stars. *Magnitude* is Latin for bigness. Arcturus is one of the most rapidly moving of all the flying stars, and is believed to travel about one hundred miles every second.

Another easily-seen constellation looks very like a big W, ˙.˙.˙, in the sky, and is called Cassiopeia, the lady in the chair. It can never be mistaken.

A beautiful white star of the first magnitude is Vega, in the Lyre, lying beside the Milky Way. It is specially interesting, not merely because it is one of the most beautiful stars in the sky, but because careful study shows that it is in the direction of this star that the sun, and we with it, are now moving, at the rate of about twelve miles in every second of time.

Quite near to Cassiopeia is Perseus. This can often be seen as a great L below the great W, and it is interesting because one of its stars is the celebrated double star Algol, which is really two stars, one bright and the other dark. They revolve round one another, so that every few days the dark one partly eclipses the bright one, and so Algol gets brighter and less bright every few days from age to age.

THE FINE SPECTACLE WE CAN SEE IN THE SKY ON A FEBRUARY NIGHT

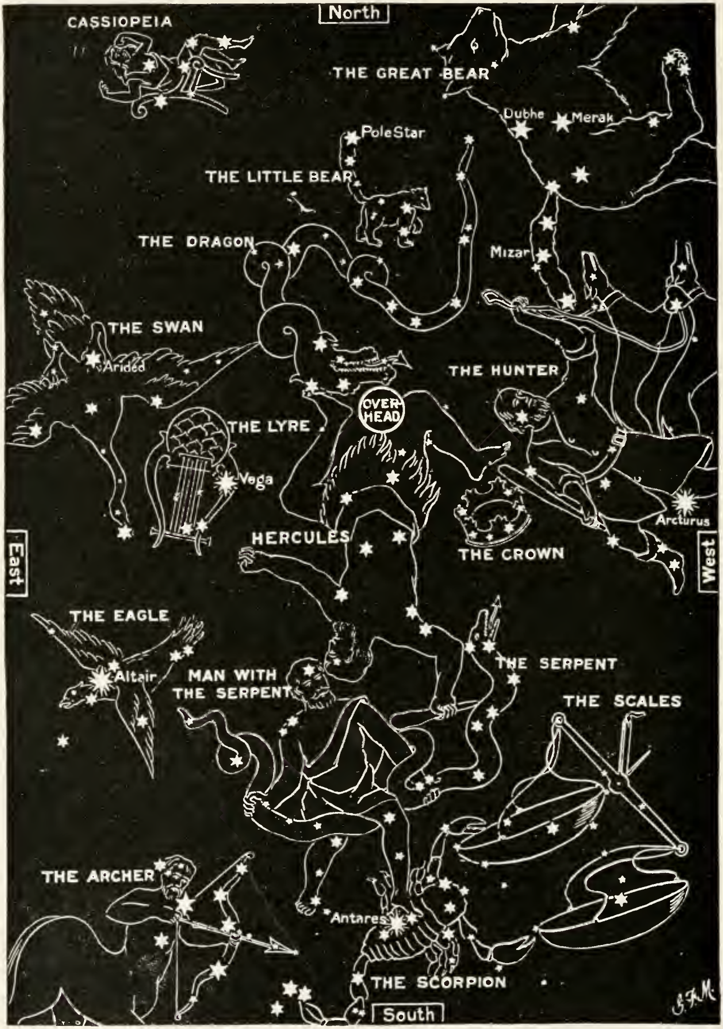
The map of the stars in winter, shows the magnificent spectacle that we may see—and should look for—any fine evening in February and thereabouts. Below the L of Perseus, not to the left like Capella but to the right, and lower than Capella are the Pleiades. There is nothing in the sky like this wonderful group of stars. It is a true constellation, for the stars making it are really together. With the unaided eye we can see about seven if we are fortunate; with a glass we can see many more. With a telescope and a camera we can print the images of about thirty thousand stars in this mighty group: stars and nebulæ too. In no other part of the sky is there such a tremendous amount of matter gathered together as in the Pleiades. Now run your eye down, and to the left from the Pleiades, and you come to the wonderful red star of the first magnitude called Aldebaran. Go on in the same line, and you reach the greatest and most splendid of the constellations, Orion. The map clearly shows how the stars of Orion make the figure of a great huntsman, with three fine stars in his belt, and three smaller ones forming the blade of his dagger. The middle one of these three last is really the most wonderful thing in the sky—it is not a star, but the Great Nebula of Orion, out of which at least six fine stars have already been formed, and doubtless many more will be formed, throughout the countless ages to come. Now look downwards and to the left from Orion, and you will see Sirius, the brightest star in the whole sky—

THE MAP OF THE STARS IN SPRING

To read these star-maps, stand facing the south and hold the map above the head with the top pointing north.

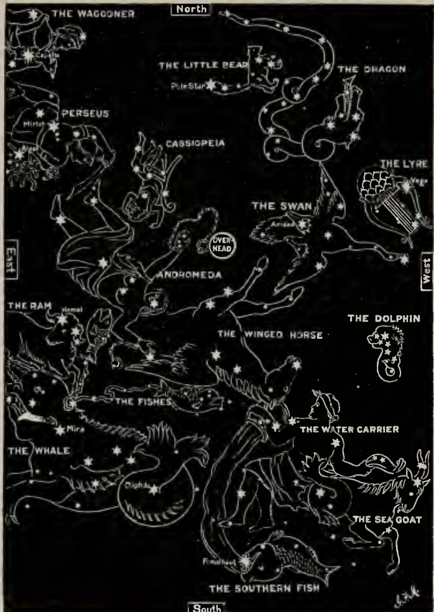
As we look up at the sky at night and see the stars shining, we notice that most of them are clustered together in groups. These groups are called constellations, a word that means simply "stars together." Some of these constellations have curious names, because the people of ancient times named them after their gods, or after things which the stars were thought to resemble. As we look at these groups of stars, it is impossible for us now to see any resemblance to the things, but some modern astronomers suggest that perhaps the positions of many of the stars, as seen from the earth, have changed during the centuries, and that the groups did at one time somewhat resemble the creatures named. In these maps we see the outlines of the constellations as ancient people drew them.

MAP OF THE CONSTELLATIONS IN SUMMER



The grouping of the stars into constellations supposed to represent animals and other things has been continued by modern astronomers because it has proved convenient for so long and any change now would cause confusion. One of the names for a group of stars, the Plow, is a good and useful one because the seven bright stars that form the tail and back of the Great Bear as seen in this picture, really have the shape of a plow and we can easily find the Plow in the sky. After giving them names, the ancients built up many fairy tales round the constellations, which professed to tell how the stars came to be there. The Great Bear is the most easily seen of all the constellations and two of its stars point almost in a straight line to the Pole Star which is always to the north of us.

MAP OF THE STARS IN AUTUMN AND IN WINTER



We have all heard of the Zodiac, the belt in the heavens within which the sun and the principal planets move. The best known of all the constellations are those which lie within the Zodiac. They are twelve in number, and some of us have learned a little rhyme at school to help us in remembering their names. It begins like this: "The Ram, the Bull, the Heavenly Twins; and next the Crab, the Lion shines, the Virgin and the Scales." The other five groups in the Zodiac are the Scorpion, the Archer, the Goat, the Water Carrier, and the Fishes. We can see all the constellations of the Zodiac in these four star-maps, and can then find them in the sky. These names were given at least 2500 years ago, and it is said that the Ram and the Archer were the first two constellations to be marked out and named. Of course many other constellations have been named in more recent times.

The two earliest Greek writers whose works have come down to us, Homer and Hesiod, refer to some of these constellations by the same names that we give them today. They speak of the Bear or the Wagon, part of which is also known to us as the Plow; of Orion, whose sparkling belt of three bright stars we all know so well; of the Dog of Orion, with its brilliant starry nose formed by Sirius; and of the Pleiades. All of these constellations are shown in this picture of the sky in winter. The Bible, also, in those parts of it which come to us from more ancient times, refers to stars and constellations which have been identified as the Pleiades, Orion, Arcturus, and the twelve signs of the Zodiac. We can read of these by name in Job xxxviii, 31, 32.

"the leader of the heavenly host." We must not suppose, however, that. if we could see all the stars in a line at equal distances from your eyes, Sirius would be the biggest. Sirius, like Algol and thousands of other stars, is really a double star. Its companion is dark, but never gets between Sirius and us, so that the brightness of Sirius does not change.

The wonderful sight you can see about bedtime

Now we have come down the right side of this map, which really shows us all the greatest glories of the sky, but there are three splendid stars in it still which must be mentioned, and can easily be recognized. These are Castor and Pollux, in the heads of the twins or Gemini, and Procyon in the Little Dog.

If you learn these few stars and look out for them when there is a chance, they will be easily remembered, and will always make the sky on a fine night vastly more interesting than it would otherwise be.

We might think at first that there was nothing to find out about the brightness of the stars. Anyone with eyes in his head can see that Sirius is brighter than Arcturus, and that Arcturus is brighter than any of the stars in the Pleiades. Also it is not difficult to think of ways of measuring these differences. For instance, we may compare the length of time it takes for various stars to print an image of themselves on a particular kind of photographic plate. If we assume—though we really may not—that the light of all the stars is the same in quality, so far as its affecting a photographic plate is concerned, then we have here a means of measuring the comparative brightness of the stars.

Why we cannot understand the real brightness of the stars

But, when we come to think of it, we shall see that neither by this method, nor by the simple use of our eyes, nor by any other means of the kind, can we ever learn what is the brightness of the stars. We can learn how bright they appear to us, we can learn the comparative intensity of the light from them when it reaches us; but that is a very different thing. The little moon, shining by reflected sunlight, is vastly more bright than Sirius, which is probably far brighter, really, than a hundred suns. The distance makes this difference.

What we can see and learn, then, by these means, is only the *apparent brightness* of the stars. Yet the star that seems to us the brightest in the sky, which is Sirius, might be really the faintest, and might shine brightly only because it happened to be much nearer than any of the others. Therefore, we can only learn anything about the *real* brightness of the stars by taking into account their distance.

Their distance is the first great problem of the stars. All over the world astronomers are working at it, and now we do know the distances, in a very general way, of a fair number of stars. This is how they are found.

How men found out the distance of the stars

If a thing is very near your head, and you change the position of your head, the apparent position of the thing changes. Even if you look at it first out of one eye, and then out of the other, its apparent position changes; and if you know the distance between your two eyes, you can in this way measure the distance of the thing you are looking at. Now, in the case of a thing like the moon, or a planet, we can change our position of sight by simply noticing where it appears to be when seen first from one part of the earth, and then from another, perhaps hundreds of miles away. This baseline of a few hundreds of miles is quite enough in such cases, just as the base-line no longer than the distance between your two eyes is enough for a pencil held in front of you. But the stars, even the nearest of them, are so far away that any base-line taken on our little earth is far too short.

What, then, can we do, for we cannot leave the earth? We can use the movement of the earth round the sun. We can look at the star on a certain night, and then look at it again six months later, when the earth is on the other side of the sun. This gives us a base-line about 186,000,000 of miles long—twice the earth's distance from the sun—and that is just long enough to allow us to notice a measurable difference in the apparent position of some stars, and so we can measure their distance. But there are many cases in which we notice *no difference* even when we use this tremendous base-line. Such stars are unimaginable distances away.

HOW MEN CAN TELL THE "WEIGHT" OF STARS THAT ARE OUT OF SIGHT

It is sometimes said that we can weigh the stars, but weight is not the right word to use here. By the weight of a thing, such as this book, we mean simply the amount of pull due to gravitation between it and the earth. If the earth were suddenly to become nothing, the book would lose nearly all its weight, and have left only that due to the pull of the sun. But the amount of stuff in the book would be, of course, the same as before. This amount of matter we call its *mass*, and it is the mass of the stars that we can measure, or at least try to measure. Their "weight" means nothing, though if we knew their mass we can say what their weight or gravitation pull would be at the surface of the earth.

We can measure the mass of a star sometimes when it has another star near it, for we can notice how its movement is affected. For instance, we know an almost endless number of double stars in the heavens—a pair of stars revolving round each other. They move in accordance with their gravitation pull for each other, and that depends on their mass, so that we can measure it. Thus we can even measure the mass of stars we cannot see, which is a great triumph for astronomy.

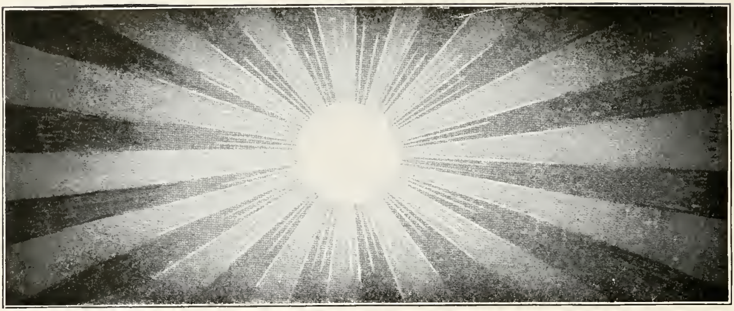
HOW MEN TRY TO FIND OUT THE SIZE OF THE STARS

But we are not completely baffled, for if we can learn certain other facts about a star, then we can at least *guess* its probable size. If, for instance, we know its distance, if we know its brightness, and, still more, if we know the amount of material in it, then we shall not be far from being able to guess what its probable size must be. But these things are very difficult to find, and the results are not very certain or precise; so the most we can say is that probably this star, or that, must be so many times as big as the sun—and that is usually the case—since it gives out so much more light.

The last point about the stars which we must mention here is their number. To find this, we need more than the eye helped by the largest telescope. We must use a photographic plate, which can see more stars than the eye, simply because the substances in the plate are more readily affected by the light of the stars than are the substances in the screen or retina of the human eye. The number of stars thus to be found is about one hundred millions.

HOW MANY STARS ARE THERE?

Also we do *not* find that, with improved telescopes and cameras, the number of the stars increases, as we should expect it to do if their number were really endless. On the contrary, we have good reason to believe that there is a limit to the number of both the visible and invisible stars.



HEAT AND LIGHT—THE SUN'S GIFT TO THE EARTH

WE ARE all familiar with the fact that the light and heat which we enjoy from day to day comes directly or indirectly from the sun. When we burn coal or wood we liberate the imprisoned sunlight which fell upon the earth long ages ago. Each day brings a new gift of life—giving and life-sustaining warmth and light directly from the center of our solar system. But the question which must often have presented itself to the reader is—how does this light and heat reach the earth and what is their real nature.

Now it was once thought that light consisted of tiny particles shot off at great speed from luminous bodies such as the sun and that the striking of these particles, or corpuscles as they were called, upon our eyes gave rise to the sensation of sight. As the result of many experiments and much study this explanation was long ago found to be untrue and we now know light to be of an entirely different nature. Our ancestors also held incorrect notions as to the nature of heat. They supposed heat to be a subtle and weightless fluid called caloric which might enter into and pass out of bodies. Today scientific knowledge has so far advanced that we know that heat is not a substance at all.

The modern theory concerning the nature of heat and light is that, under some conditions at least, they are one and the same thing and that they have a common origin or beginning. We have read in the chapter describing the sun that it is made up of many substances such as iron, sodium, carbon, copper, etc., and that these elements are at a very high temperature. We also learned in our study about chemistry that a substance such as carbon, for example, is made up of very minute particles called atoms. It is now thought that these atoms are in turn made up of still smaller parts known as electrons. The nature of these electrons will be spoken of when we come to study about electricity.

When a substance is very hot the atoms, and the electrons which go to make up the atoms, are in very rapid but regular vibratory motion. Some of the electrons may be vibrating much more rapidly than others.

Now there exists everywhere in the universe a strange and invisible something which we call ether. It is probably not a gas or liquid or solid but is something quite different from ordinary matter. It not only fills all space, extending out beyond the sun and the most remote star, but is in everything, that is, the particles of matter which go to make up this book are embedded in it. Though the ether is invisible yet we know that such a thing exists because of its effect in the world, just as we know that wind exists, not because we see the wind itself, but because we can observe its effect. Though we do not know very much about the ether, we do know that it has certain characteristics, or, as we may say, properties, which make possible the transmission of a disturbance through it. Imagine a mass of gelatine such as we eat for dessert at dinner. If we touch one side of the gelatine with a spoon a tremor or wave motion passes through the entire substance. This is similar to the behavior of ether when disturbed in certain ways.

We will remember from our study of sound that a vibrating piano string generates a disturbance in the air which we call sound waves. Let the piano represent an atom of some element in the sun, and the strings some of the electrons that go to make up the atom. The vibrating electrons in the sun being surrounded by the all-pervading ether give rise, because of their motion, to disturbances in this strange medium. These disturbances, or ether waves, travel outward in all directions carrying some of the energy of the motion of the electrons with them. In the case of the piano we may cause a number of the strings to vibrate at the same time—bass notes and notes of higher pitch—the former giving rise to long air waves and the latter short waves. In much the same manner some of the electrons in an atom may be vibrating slowly and others rapidly. Hence both long and short ether waves may proceed simultaneously from the same atom. However the longest of these ether waves are very short when compared with sound and water waves. The sound which we recognize as middle C on the piano is about four feet in length while a wave of average length in the ether would be about as long as a thin piece of tissue paper is thick.

Another striking thing about these ether disturbances is that out in free space, that is, beyond our atmosphere, the long and short waves travel with the same speed. The actual velocity of the waves in the ether is enormous. The sun is something like ninety three million miles from the earth, an ether wave starting at the sun will arrive at the earth eight and one-half minutes later. This means that such waves have a velocity of 186,000 miles per second. We are amazed with the magnitude of such a velocity when we remember that a bullet travels at the rate of approximately half a mile a second; sound in air travels at the rate of one-fifth of a mile a second, while an ether wave could travel one million miles a second.

It was suggested above that these waves, as in the case of sound and water waves, possess energy, that is, they are capable of exerting a force and hence doing work. Because these waves are being sent out continually from the sun, or as we say, being radiated, and because they possess energy these disturbances in the ether are spoken of as radiant energy. And so we see that the energy from the sun comes to the earth in the form of this radiant energy which is no more or less than a series of wave motions in the ether.

So far in our story we have not said anything directly about the nature of light or heat, and perhaps we have asked ourselves the question, what have these ether waves to do with light and heat. As we shall presently see it was necessary to know something about these waves coming from the far-away sun before we could easily and clearly understand what is to follow.

Now this radiant energy from the sun passes through our atmosphere and the waves strike the earth and all bodies upon it. The shortest of these ether waves are capable of affecting certain parts of the body in a most wonderful and beautiful way. Where certain of the shortest of these ether waves pass into our eyes and strike the retina we sense green, and still longer waves give us a sensation of red. The retina is not sensitive to the longest waves but we fortunately have other means of recognizing their presence, and we shall read about these long waves in the paragraphs which are to follow. For the present the important fact to be remembered is that the short ether waves, that is, those capable of affecting our eyes, constitute what we know as light. Light then is a wave motion.

And now to learn something more about the longest waves that come from the sun. In order that the facts about these waves may become plain to us we must realize a certain very important and strange fact in nature. The book in our hand may be held perfectly still but do we realize that the molecules which go to make up the paper of the book are always moving about? They never get very far from one another but nevertheless they are always in more or less rapid vibration, and this is true about the molecules of all substances about which we have any knowledge. The reason that the molecules do not fly off into space and separate from one another is that the molecules of any substance such as paper or wood or glass are very close together and have a very strong attraction for one another.

We naturally wonder what force or agency keeps the molecules in motion and whether they always move with the same speed. Here is where our long ether waves play a part. When these waves coming from the sun strike upon material substances such as wood or water or earth they cause the molecules composing these substances to vibrate more rapidly than they commonly do. If these waves of radiant energy fall upon a piece of iron, for example, for a long time the molecules of iron are caused to move very, very rapidly. Now a body that is moving rapidly possesses more energy than one that moves slowly. This is illustrated by the greater destruction wrought by a projectile moving at a high velocity as compared with the results of one having the same weight but moving slowly. We have seen that our ether waves possess energy. In the case we are studying the molecules which are given greater motion by the impinging waves receive energy from these waves and hence possess more energy as a result of their increased motion. We say the substance is being heated. The energy of the moving molecules is what we know as heat. If the molecular motion becomes less the body possesses less energy, or, in other words, it has less heat. We are to look upon these long ether waves, then, not as heat but rather as that which gives rise to molecular motion and the energy of this molecular motion is heat.

The molecular motion which bodies have when ether waves are not falling directly upon them is due to the fact that radiant energy has at some former time reached the substance, and to other reasons which will be explained later.

AIR, WATER AND FIRE

THE Greeks, when they spoke of the earth, probably meant all solid matter. Of course, they knew as well as we do that this solid matter composing the earth under our feet shows itself in many forms, such as gold and silver and iron and sand. But still, all these have a certain resemblance; they all look much more like each other than like such a very different thing as air; and so they were all grouped together under the one heading of "earth."

Of course, there are living creatures on the earth, such, for instance, as trees, and trees make the material called wood, which is different in many ways from the earth we pick up in the garden. But the Greeks recognized, quite rightly, that all living things are made out of the substance of the earth; that the earth is their *mother*, as they said. And so they still continued to include all solid things, not excepting the bodies of living creatures, as made of the one element *earth*. We now know, however, that the solid ground under our feet, and the living creatures which grow from it, are made up of many different elements, which no force, no kind of treatment, however long continued, will change into each other or will split up into different things, and we know that these are the real elements.

Now let us consider the next thing that the Greeks called an element—the air. We have already learned that it is real matter, though we cannot see it; but is it really an element, as the Greeks thought—that is to say, is it made of only one thing, which is one and the same everywhere, and which, whatever is done to it, cannot be changed into anything else or split up into simpler things? We can answer this question quite positively, for there is scarcely anything that chemists have more carefully studied than the air. *It is not an element, but a simple mixture of a number of elements* which can be sorted out of it, just as you might mix gold and silver by melting them together, and then might separate them from each other afterwards. The air is a mixture of different elements in the gaseous state. Now, we should be particular to notice the word *mixture*, because it has an exact meaning, and because, when we come to say what we must say about water, we shall find that though water is also not an element, and though it contains two elements, yet *it is not a mixture* of those two elements, but is something else.

The case of water, and thousands of other things, is rather more difficult, and that is why we have purposely taken the air first, because scarcely anything could be more simple than air. The most simple kind of stuff, of course, is one that is simply made of one element, such as gold, or silver, or iron. Nothing could be more straightforward than that. But, after all, the case of the air is not much more difficult, for anyone who has ever added milk to tea, or seen a plum-pudding, knows what a mixture is.

If you take a little sugar and a little rice, and mix them together, there you have a simple mixture.

WHAT HAPPENS WHEN TWO THINGS MAKE ANOTHER QUITE DIFFERENT

The point about the mixture of sugar and rice is this: that, however perfectly they are mixed, the sugar remains sugar and the rice remains rice. *They are mixed, but they are not changed.* After all, it is no more than if you had one grain of rice and one grain of sugar, and put them side by side. The grain of rice is still a grain of rice, and the grain of sugar is still a grain of sugar.

That may seem simple, but it is of great importance that we should understand it, because, as we shall see, two elements can be made, in certain circumstances, to unite in a special way which is very much more than mixture, and to produce something which is absolutely different from either of them, just as much as if when you mixed sugar and ground rice they both disappeared, and you found yourself with a lot of water in the cup instead. That would be more than a mixture, would it not? Something must have happened very different from simply pouring two things out of two bags into one cup, and that is all you need do to make a mixture.

What a mixture is and what a mixture is not

Now, the air is simply a mixture of elements. It is as if you took a quantity of one element in the form of a gas, made of tiny little specks called atoms—which we shall talk about soon—something like the grains of sugar or rice, and then to that you added a quantity of another element in the form of a gas, so that the tiny grains or atoms of which it was made just mixed with the atoms of the first element. It is as if you had black marbles in one pocket and white marbles in another, and you took them out and put them into a different pocket together. The black marbles would still be black, and the white marbles white, and you would simply have a mixture of black marbles and white marbles.

Now, this simple fact, that the air is just a mixture of gases, took men an exceedingly long time to find out, and it took them still longer to believe; and even now, though people know that there are different kinds of stuff in the air, they are very often slow to understand that these kinds of stuff are simply mixed, and nothing more. And even in careless books, sometimes, you will find the facts wrongly stated, so as to suggest that the air is not merely a mixture of gases, but something quite different, which we may as well know the name of now; it is called a *compound.* But that is not so; the air is not a compound.

There are two elements which make up nearly the whole of the air; their names are *oxygen* and *nitrogen*, and they are not really *combined*, but *mixed*, like the marbles in one's pocket. Oxygen and nitrogen can be combined in various ways, but in these cases they make something quite different—which is not oxygen, not nitrogen, and certainly not air. The best-known thing which is made out of oxygen and nitrogen when they are combined as a compound is called laughing-gas, which the dentist gives us so that we shall feel no pain when we have a tooth drawn.

Oxygen has been named first, though the air is not an equal mixture of these two elements, and though, indeed, there is far more nitrogen than oxygen in it; but the oxygen is far more important, though there is less of it. Just about one-fifth of all the air consists of oxygen, and just about four-fifths consists of nitrogen. Of course, these are only rough proportions, because, as a matter of fact, there is a tiny quantity of many other elements in the air helping to make up the mixture.

The lazy element that keeps by itself, even in a crowd

But though these elements are very interesting, yet they do not do anything in particular, and so they do not matter much to us. Only one of them—perhaps the best known—is called *argon*, which means *lazy*, because, though, of course, it will *mix* with anything, it has never yet been made to *combine* with anything, but always keeps by itself, so to say, even when it is in a crowd. That is why it is called lazy.

Though about four-fifths of the entire air is made of nitrogen, yet this element, as it exists in the air, is also not very important in itself, for it does practically nothing. Very different is the nitrogen that exists in the earth, where it is also found, for in the earth it helps to build up the bodies of animals and plants, and without it there could be no life.

But practically all that the nitrogen in the air does is merely to dilute or weaken the oxygen, just as you dilute strong medicine by adding a lot of water to it. If all the air, instead of only one-fifth part of it, were made of oxygen, we should scarcely know ourselves.

WE COULD NOT LIVE WITHOUT OXYGEN, NOR COULD WE LIVE WITH TOO MUCH

Oxygen as we have learned is the element which all animals and plants breathe in order to keep alive. Without oxygen they would all die at once. And this is true even of the fishes of the sea, which breathe oxygen from the air that has dissolved in the water. This is quite different, as we shall see, from the oxygen that goes to *make* the water, which the fishes cannot use. If all the air were made of oxygen we should get too much of it into our blood, and we should be probably very excited, and never rest, and live too fast. We should do what a fire does if you blow pure oxygen into it. It burns up vigorously. It is quite easy to sift the oxygen out of the air, and collect it, and when men want an intensely hot flame they make something burn with this pure oxygen instead of with ordinary air. Also, sometimes when people are ill, and cannot get enough oxygen from the ordinary air, they are given pure oxygen instead to breathe for a time, and this often helps them greatly.

Well, that is all we need read about air at present. It is mainly a mixture of two elements in the form of gases, but it is an unequal mixture, about four-fifths of it consisting of the element nitrogen, and about one-fifth of the element oxygen. There are also tiny quantities of various other elements which go to make it up.

And now we come to the fourth of the things which the Greeks thought were elements, and that is *water*. This is, of course, one of the most wonderful, interesting, and important things in the world, though it is so common. It is to be found everywhere. There is a vast quantity of it in the air in the form of a gas or water-vapor; enormous quantities of it occur in the form of ice in the neighborhood of the two Poles of the earth—the North Pole and the South Pole. In its liquid form it covers three-fifths of the entire surface of the globe. Fully three-fourths of the entire substance of our own bodies consists of it, and this is practically true of all living creatures.

There could be no life without water. Most of the changes that occur on the surface of the earth are due to the action of water. There are very few forms of matter, indeed, which will not dissolve in water to some extent; and this applies not only to solid things like sugar, and to liquid things, but also to gases.

WATER IS MADE UP OF SIMPLER THINGS THAT ARE NOT WATER

One of the most important questions about the planet Mars is as to the presence of water there; and one of the most important facts about the moon—a fact which explains why the moon is lifeless, and why scarcely anything ever happens on its surface—is that there is no water on it.

For many ages men believed that water was an element. There was no reason to believe that water could ever be split up into anything simpler. But we now know that water is not an element, and few more important discoveries have ever been made than this.

The truth is that water is made up of simpler things which are not water. Now, the first thing that will occur to you is perhaps that water, like the air, is a mixture. Obviously, it is not a mixture of gases, for a mere mixture of gases would itself be gaseous, as the air is; but perhaps it is a mixture of liquid things, just as milk is. But this is not so. *Water is neither an element nor a mixture*, but is what is called a *compound*, and as most of the things of which the earth is made are compounds, we must be sure we understand what this means before we go any further.

THE ATOMS WHICH FORM MOLECULES

If you take a heap of sand, you know that it is made up of tiny grains, each of which is itself a grain of sand. Now, in exactly the same way, if you take a tumbler of water, it is made up of tiny little parts or particles, each of which is a particle of water; and the whole bulk of the water is made up of a number of these as the heap of sand is made up of grains of sand. These particles of water are so small that, if you could imagine a row of them, it would certainly need many millions of millions of them to stretch out as far as an inch.

Now, there is a special name for these tiny parts or particles of anything, and as this name is used all over the world in describing them, we must learn it. The word is *molecule*—pronounced molly-cule—and it is the Latin name for a *little mass*. Now if we want to find out what water really is, the best way for us would be to take one of these molecules—in imagination, for, of course, they are far too small for us to do it in reality—and find out what it is made of. This is, of course, really impossible so far as one molecule is concerned. However it is possible for the chemist to take apart a large number of such molecules at once and hence we are absolutely sure of what we should find if we were able to take one molecule of water and pull it to pieces.

Now, let us imagine that we have this molecule before us. The first thing we find is that it consists of three pieces. Every molecule of water, everywhere and always, whether in your body, or in the air, or in the sea, or in the form of ice, or in the air of the planet Mars, consists of these three pieces joined together. Otherwise it would not be water, and nothing else is water, however much it may look like water. That is one of the things we are absolutely certain of.

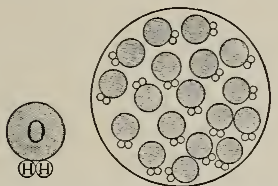
Further, because water is always made of molecules consisting of these three parts, all water everywhere, on the earth, or on Mars, or on a planet belonging to some other sun than ours a million million miles away, always behaves in exactly the same way as all other samples of water. It has its laws, which depend upon its nature; and as its nature is the same everywhere, so its laws are the same everywhere. We can watch the snow-caps of Mars melting under the influence of the sun's heat, just as snow melts on the earth.

Everywhere in the universe, water under the same conditions will boil in the same way, will melt in the same way, will freeze in the same way, will dissolve the same amounts of the same things, will form drops in the same way, will have exactly the same properties of every kind; simply because whenever and wherever you find water it is one and the same thing.

Now, what are the three parts of which the molecule of water is always made? This is, on the whole, the most important molecule of any kind that we know in the universe, and as it is also one of the simplest, it is a good one to begin with. The picture below is an imaginary picture of the way in which a molecule of water is made.

WHAT A MOLECULE OF WATER WOULD LOOK LIKE IF YOU COULD SEE IT

We say an imaginary picture because, though we have drawn the three parts as if they were round, we really know nothing about that, since we have never seen them. We do know that they exist, and that by some



The tiniest part of water is made up of three parts like the left picture, called a molecule; the large picture shows how these together form a drop of water.

force or other they are held together. We also know, by the way, that this force is extremely strong, because it takes great trouble and effort to break up a molecule of water; that being the reason why for so many ages men thought that water was an element.

The diagram represents a single part, or molecule, or unit of water. A lot of water—like a tumbler of water or the Atlantic Ocean—is made up of a number of these molecules taken together. But a single molecule is the smallest possible portion of water that can exist. If you break it up so that its three parts do not hang together, then it is no longer water at all, but is simply a mixture of the two kinds of stuff which make up water. This we must be quite clear about, for it is the difference between a *compound* and a *mixture*, and that is one of the most important differences in the world.

HOW TO MAKE ONE O CATCH HOLD OF TWO H's

If you had in a jar—and this is quite easy—a number of the kind of things marked H in the picture, and also a number of the kind of things marked O, and even supposing that you had twice as many of the H as of the O, so that the proportion between the two was the same as it is in water, yet that jar would not contain water, but only a mixture of the stuff called H and the stuff called O. That mixture would not be water, and would not look like water; and the astonishing thing is that, even at the ordinary temperature of the room, this mixture would not be liquid at all, but just a mixture of gases, and by looking at it you could not possibly tell it from that other mixture of gases which we call air. In a little while we shall see how it would be possible to do something with this mixture of H and O so as to make every O catch hold of two H's and form a molecule of water; and then, instead of the mixture of gases that we had before, we should have a tiny drop of water, and this water would actually be made out of that mixture of gases.

Now, that is what water is—a compound made out of the two gases which up to now we have called by the first letters of their names, H and O.

Now, what do H and O stand for? First of all let us take O, because we have heard more about it already. O stands simply for the gaseous element *oxygen*, which we talked about in connection with the air.

EACH MOLECULE OF WATER HAS TWO HYDROGEN ATOMS AND ONE OF OXYGEN

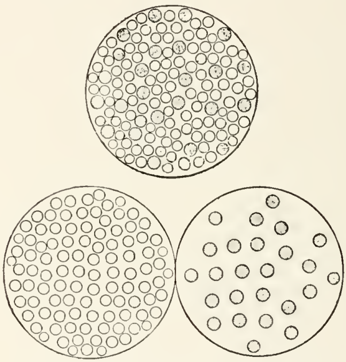
H stands for another gas, called *hydrogen*, and hydrogen is really a very good name for it, and tells us what it is, for the word simply means the thing that *produces water*, and H, or hydrogen, is simply the gas with which oxygen produces water. Only it will not do for them to be merely mixed, but they must be *combined*, and they must be combined in the special way shown in the picture—two H's for one O. There is another way in which hydrogen and oxygen can combine, in which there are two H's for two O's, so that each molecule of this other substance consist of four parts instead of three. But this other substance is not water; it is not even a special kind of water, but is something quite different.

Now, there is another word which we must learn here. The tiny specks of H or of O which go together, two of the first to one of the second, in order to form a molecule of water are called atoms, and so we can say now that *water is made of molecules, and each molecule contains two atoms of hydrogen and one of oxygen.*

In the drawing the O has been made large and the H quite small, for the reason that each oxygen atom really weighs as heavy as sixteen hydrogen atoms. Therefore, though there are two hydrogen atoms to one oxygen atom in every molecule of water, oxygen forms eight-ninths of all water, which is made up of one part of hydrogen and eight parts of oxygen.

So when we speak of an element like oxygen or gold, we simply mean something consisting of a number of atoms all of the same kind. When we speak of a compound, such as water, we mean something made of molecules which themselves are made up of atoms of at least two kinds; and when we speak of a mixture, we simply mean that two or more kinds of atoms, such as oxygen and nitrogen, have got mixed up together.

Now, atoms are most important things, for it is their properties that give the elements their properties. Gold is gold because it is made of atoms of gold; and oxygen is oxygen because it is made of atoms of oxygen. And, just as we saw that all the molecules of water are the same everywhere, and that all water everywhere is made of the same kind of molecules, so also we must know that all the atoms of any particular element are the same. There are atoms of oxygen in this page before you, and in your eye, and in the sun, and in water, though in water



The pictures show how atoms mix. The dark balls are like atoms of an element, such as oxygen. The light balls are like atoms of another element, such as hydrogen. When the two mix, we get a mixture of elements, as in the third picture. The air is such a mixture. Oxygen and hydrogen make such a mixture, but that is not water.

they are combined with hydrogen. But all atoms of oxygen everywhere are all the same, and we can know them because they are the same.

Finally, let us remember the way in which water can be made. If we take the right proportions of oxygen and hydrogen—that is, eight times as much oxygen as hydrogen, so as to give us two hydrogen atoms for every one of oxygen—and if we let them mix in a jar, and if then we pass a spark of electricity through them, the atoms of the two gases will rush towards each other, each atom of oxygen taking two of hydrogen; and the two gases will totally disappear, leaving in place of them a tiny drop of water.

When these two gases are once united to form water it is with great difficulty that they are again separated. It is interesting to note that the same agency which caused two gases to combine, in the above experiment, may be utilized to separate water into its constituent parts. If we send an electric current through some water, to which has been added a small amount of acid, we shall find that gas will bubble off from both the wires that conduct the current into the liquid. If we examine these gases carefully we shall find gas is being produced twice as rapidly at one wire than at the other and a simple test will prove that this gas is hydrogen. The gas being evolved at the other terminal is found to be oxygen, and as these gases are produced the quantity of water diminishes. The electric current has separated the water into its elemental parts.

This however is not the only method by which the decomposition of water may be brought about. If water in the form of steam is raised to a very high temperature by bringing it in contact with burning anthracite coal it will also be broken up into hydrogen and oxygen. This method is employed on a large scale commercially in producing what is known as "water gas."

If we want to express very shortly the nature of water—that is to say, the make-up of a molecule of water—we can simply write down a big H for hydrogen and put a little 2 beside it to show that we want two hydrogen atoms; and then we can take a big O to stand for oxygen, and put a little 1 beside it to mean that we want one oxygen atom; and then we can write them together like this, H_2O_1. In order to save trouble we usually omit the 1, and so, when we want to write water in this special way, we simply say H_2O, and that represents the molecule of water, made up of two H, or hydrogen, atoms, and one O, or oxygen atom.

In fact scientists frequently use such abbreviations or symbols for elements and compounds. Sometimes more than the initial letter is used as the symbol of an element, and often this abbreviation is taken from the Latin word for the element. For example, Fe stands for *ferrum*, the Latin word for iron; Ag for *argentum*, meaning silver; and Au for *aurum*, the Latin equivalent for gold.

Reference was made in a previous paragraph to the force which holds the atoms together to form the molecules of water. This force is spoken of as *chemical affinity* and is one of the most remarkable forces in the world. Just what the nature of this force is no one at present knows, but we do know that this force acts much more strongly between certain atoms than between others. As we have already learned, the chemical affinity between the atoms of oxygen and hydrogen in water is very great but in a substance such as iron rust, which is a compound of the elements iron and oxygen, the affinity between the iron and oxygen is not nearly so strong as between hydrogen and oxygen in water.

Not only is there a difference between elements with respect to the strength of their chemical attraction, but they also differ in the *manner* in which they unite with other elements. For instance in the case of water the element oxygen unites with *two* atoms of hydrogen while in the case of a certain compound of zinc used in making paint the molecules are made up of one atom of oxygen and *one* atom of zinc. It would take us too far to inquire into this point further at the present time but it is mentioned here to show that the uniting of elements to form compounds is a wonderful process—a process however which follows certain definite and fixed laws. It has already been pointed out that a water molecule is always composed of the same elements in the same proportions, and the same thing might be said concerning the compound of zinc just referred to, and about any compound in the world.

Before leaving the subject of water it is well for us to realize the extent to which this compound enters into the composition of the countless different substances in the world. Although water is not an element yet it acts in the world, for all practical purposes, as if it were an element. The water existing in nature—in the earth, in the bodies of living creatures, in the sea, and in the air—goes on existing as water from year to year just as if it were an element and not the compound that it is. This is one of the singular and very important facts about this common but necessary compound.

The accompanying picture has been prepared to show the extent to which water enters into the composition of various substances. Each of the small pictures has at its side a pillar, which we may call a scale or measure, marked off into a hundred parts by little lines, and the thick black line in the middle shows how many hundredths of the thing in the picture are made of water.

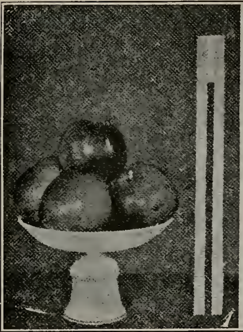
In the picture, we are shown that eighty-two parts out of a hundred of apples consists of water. The remaining eighteen parts of a hundred consist of various other things which are not water. We borrow words from the Latin in order to express this way of measuring things. We take the Latin word for a hundred, which is *centum*; and another Latin word *per* meaning "for" or "by"; and so we get the phrase *per centum*, usually written *per cent* for short. Hence we say in the case of apples, for instance, that they are 18 per cent solid matter and 82 per cent water. The long black line in the scale in the picture tells the eye just what these words tell the mind.

Picture 2 shows that strawberries have only 10 per cent of solid matter, and 90 per cent of water. Picture 3 shows that the cucumber has only 5 per cent solid matter, and 95 per cent of water, and so on through the list. And what is true of the substances shown in the illustrations is also true of many others. Hence we are led to realize how widely water is distributed throughout nature and how important a part this compound plays in the life of the world.

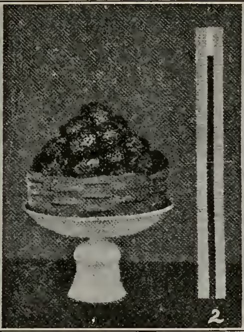
And now we come to consider the fourth thing which the Greeks thought was an element—namely, fire. It is not at all surprising that the ancient peoples made the mistake of thinking fire to be something separate and distinct from ordinary matter. As we watch the flames play about a burning object and acting much as if they were alive it is not difficult to understand how Plato, one of the most learned men the world has ever known, concluded that all combustible substances must contain a certain element which enabled them to burn. Later in the world's history this supposed element came to be known as phlogiston, from a Greek word meaning, "I set on fire." According to this theory combustion consisted in the escape of phlogiston from the burning substance. In short, fire was escaping phlogiston.

About the time of our Revolutionary War a French scientist by the name of

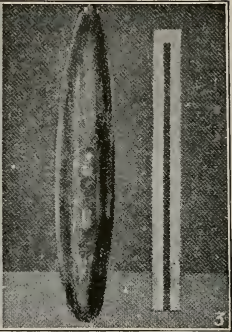
THE WATER THAT IS EVERYWHERE



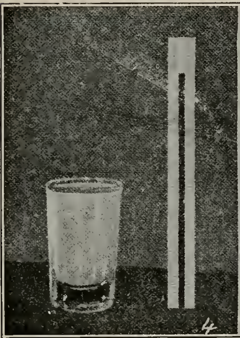
82 parts out of 100 of apples are made of water.



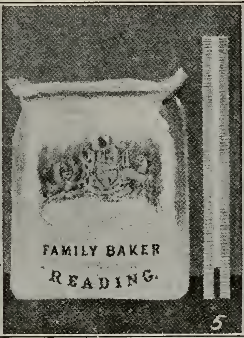
90 parts out of 100 of strawberries are made of water.



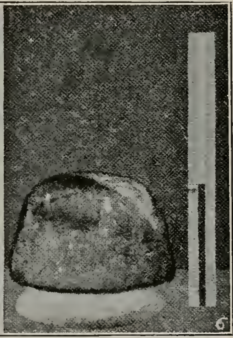
95 parts out of 100 of a cucumber are made of water.



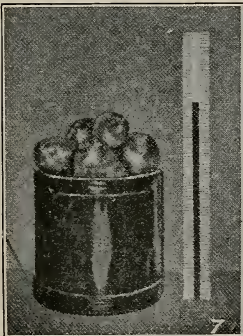
87 parts out of 100 of milk are made of water.



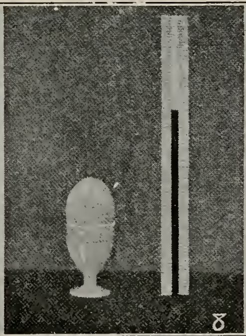
12 parts out of 100 of flour are made of water



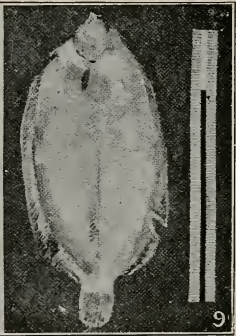
This loaf contains more water than the flour beside it.



Three-quarters of a potato is made of water.



About two-thirds of an egg is made of water.



About four-fifths of a fish is made of water.

These pictures show us how water comes into everything. It is wonderful to think that a cucumber can hold together as a solid thing, although 95 parts of it are water and only 5 are solid matter. Each of these pictures has a little measure beside it, marked off into 100 parts by little lines, and the thick black line shows how many of these parts are made of water. The black line up the center of the scale stands for the water, the white line stands for the solid matter in all these things.

Lavoisier performed a number of experiments which revealed the true nature of the process of combustion and gave us a correct understanding of what fire really is. We now know that fire is nothing more nor less than incandescent matter—usually the element carbon. The process known as burning or combustion is what the chemist is in the habit of calling a *reaction.* By reaction he means the breaking up of a compound into its elements, or the uniting of elements to form a compound, the latter form of reaction being illustrated by the formation of water by passing an electric spark through a mixture of hydrogen and oxygen.

If we lay aside a bright piece of copper for a considerable length of time we know that the metal will become tarnished. What has happened? A slow *chemical reaction* has taken place. Oxygen from the air has gradually united with the metallic copper on the surface to form a compound known as copper oxid. Common muriatic acid is a gaseous compound dissolved in water. It is composed of hydrogen and an element known as chlorine, and its symbol is HCl—one atom of hydrogen and one of chlorine compose a molecule. Now, if we pour some of this acid onto a piece of metallic zinc we say the acid "dissolves" some of the zinc. What we really mean is that the zinc and the acid have reacted chemically to form a new compound, and this new substance is known as zinc chlorid ($Zn\ Cl_2$). Zinc has a much stronger affinity for chlorine than does hydrogen, and so the molecules of the acid are broken up and new molecules are formed, the hydrogen atoms being set free and escaping as a gas. This is a somewhat more complex reaction than the oxidation of the copper.

When the chemical reaction just described takes place a definite though small amount of heat is produced as a result of the reaction. Now many chemical reactions result in a large amount of heat. Carbon, and a number of other elements, have a very strong affinity for oxygen. When the union of these two elements takes place very rapidly a large amount of heat is produced. Indeed so great is the heat that the particles of carbon are actually heated to incandescence. In other words, *combustion or burning is a rapid chemical reaction between carbon, or some other element, and oxygen.* Their action gives rise to intense heat which causes the combustible material to glow as do the coals in the grate or the gaseous elements in a candle flame. The burning of a building is a chemical reaction on a grand scale.

The question might naturally arise, what happens when we "light" the fire and why is it necessary?

By applying fire to a combustible material we raise the temperature of the substance to the point where the reaction will begin, and after the union of the elements once starts the heat generated by the reaction itself is sufficient to continue the process. The temperature to which we must heat a substance before it will begin to burn is known as the *kindling point.* We can thus see that combustion will not take place where there is no oxygen, and that if this chemical process were to begin at ordinary temperatures all the combustible material in the world would burn up at once.

CHEMICAL ELEMENTS

A tabulated statement of the occurrence, preparation, properties and uses of all important elements.

Abbreviations:—At. wt., atomic weight; M. wt., molecular weight; Va., valence; S. G., specific gravity; M. P., melting point; B. P., boiling point. All temperatures are centigrade.

Definitions of Chemical Element, Atomic Weight, Symbol, Formula, and Electrolysis will be found at the end of the Table.

Note:—The M. wt. of gases divided by 28.95 gives the density compared with air.

Aluminum, Al. At. wt. 27.1. Va. III. S. G. 2.6 M. P. 658°.	**Occurrence.** Very abundant in clays, feldspars and many other silicate rocks; also as the oxide in emery, ruby, sapphire, etc. **Preparation.** Electrolysis of the purified oxide dissolved in molten cryolite. **Properties.** Silver white, ductile, malleable at 120°, high tensile strength, the best conductor in proportion to weight. Stable at ordinary temperatures, attact only by the strong acids, except nitric acid, and by caustic alkali. Has a powerful affinity for oxygen at high temperatures, therefore it is a most powerful reducer of other oxides, generating high temperatures in the action, which are exceeded only by the electric arc. Also used for cooking utensils, electrical conductors, and paint. Clays and alum are very important compounds.
Antimony, Sb. At. wt. 120.02. Va. III and V. S. G. 6.7. M. P. 630°.	**Occurrence.** Mostly as stibnite (Sb_2S_3). **Preparation.** Roasting stibnite to oxide and reducing with carbon. **Properties.** White metal. brittle, strongly crystalline. Molten metal expands on solidification, and its alloys give, therefore, sharply defined castings, *e. g.*, type metal. Stable in air, burns when heated, and unites readily with the halogens. It is used mostly in alloys, *e. g.*, type metal, Britannia metal and Babbitt metal (for bearings).
Argon, A. At. wt. 39.86. M. wt. 39.86. B. P. 186°.	**Occurrence.** About 1% of the air. **Preparation.** Carbon dioxide, water vapor, oxygen and nitrogen are successively removed from air by absorption. The residue is mostly Argon. **Properties.** Monatomic gas, absolutely inert, enters into no chemical combinations. Identified by its characteristic spectrum.
Arsenic, As. At. wt. 75. Va. III and V. S. G. 5.7.	**Occurrence.** Free, arseno pyrite (FeAsS), and the sulphides orpiment and realgar. **Preparation.** Roast ores, and reduce oxide with carbon. **Properties.** Steel gray, tarnishes to dull gray, coarsely crystalline. Sublimes at 450°. Burns with pale blue flame, combines readily with the halogens. The most important compounds are white arsenic (As_2O_3) and its derivatives, and the salts of arsenic acid (H_3AsO_4). Used mostly for insecticides, also in medicine.
Barium, Ba. At. wt. 137.37 Va. II. S. G. 3.6.	**Occurrence.** Barytes ($BaSO_4$) and witherite ($BaCO_3$). **Preparation.** Electrolysis of the molten chloride. **Properties.** A silver-white metal, decomposes water, very active. Its vapors give a green flame. Hence it is used in pyrotechny. Important compounds are BaO_2, used in manufacturing oxygen and hydrogen peroxide, and $BaSO_4$, used in paints as an inferior substitute for white lead. $BaSO_4$ is highly insoluble.
Bismuth, Bi. At. wt. 208. Va. III. S. G. 9.9. M. P. 266.5°.	**Occurrence.** Free, and as trioxide, and trisulphide. **Preparation.** Roasted in air and reduced with carbon. **Properties.** Bright crystalline metal with pinkish tint; brittle. Stable in air, burns when heated. Used in alloys with low melting points. The subnitrate is used in medicine.
Boron, B. At. wt. 11. Va. III. S. G. 2.4.	**Occurrence.** In boric acid and borax. **Preparation.** The oxide is heated with magnesium. **Properties.** A greenish black powder. Boric acid (H_3BO_3) and borax ($Na_2B_4O_7$) are important compounds.

CHEMICAL ELEMENTS — Continued

Bromine, Br. At. wt. 79.92. M. wt. 160. Va. I. S. G. 3.2. B. P. 59°.	**Occurrence.** In sea water and salt deposits, as bromides. **Preparation.** Bromides are treated with sulphuric acid and manganese dioxide, and the Br. distilled off. **Properties.** Dark red liquid, bad odor, very corrosive and poisonous. Combines with most elements but with less energy than chlorine. Used in preparation of dyes. Bromides are used in medicine and photography.
Cadmium, Cd. At. wt. 112.4. Va. II. S. G. 8.6. M. P. 321.7°.	**Occurrence.** In Zinc ores. **Properties.** A silver-white metal, burns in air, and is fairly active. Uses, in alloys with low M. P. The sulphide is a yellow pigment. The iodide is used in medicine.
Cæsium, Cs. At. wt. 132.81. Va. 1. S. G. 2.4.	Rare element, strongly resembling potassium. The most active of the metals.
Calcium. Ca. At. wt. 40.09. Va. II. S. G. 1.54. M. P. 760.	**Occurrence.** As carbonate in limestone, marble, chalk, etc. As sulphate in gypsum, as phosphate, fluoride, and in many silicates. **Preparation.** Electrolysis of the fused chloride. **Properties.** A white crystalline metal. Decomposes water, burns in air, and is very active. Uses: Yields many useful compounds, *e. g.*, lime, which is the oxide; slaked lime, the hydroxide; bleaching powder and calcium carbide.
Carbon, C. At. wt. 12. Va. IV. S. G. 1.9—3.5.	**Occurrence.** In two crystalline forms, diamond and graphite, and in several amorphous forms: charcoal, coke, lamp black, gas carbon, and coal. Each has its peculiar important uses. **Properties.** Very stable at ordinary temperatures, very active toward oxygen at high temperatures. It forms carbon dioxide, the basis of carbonic acid, and the poisonous monoxide. The compounds of carbon form the field of organic chemistry.
Cerium, Ce. At. wt. 140.25. Va. III and IV. S. G. 7.0.	**Occurrence.** In cerite and monazite. **Preparation.** Electrolysis of the molten chloride. Burns with dazzling brightness. One per cent of the dioxide is used in Welsbach mantles.
Chlorine, Cl. At. wt. 36.46. M. wt. 71. Va. I, V and VII. B. P.—33 6°.	**Occurrence.** In salt (NaCl) and other chlorides. **Preparation.** Electrolysis of chlorides, or oxidation of hydrochloric acid. **Properties.** A greenish-yellow gas of intensely bad odor, very corrosive to mucous membranes, combines with most elements with great energy. Used for bleaching and disinfecting.
Chromium, Cr. At. wt. 52. Va. II, III and VI. S. G. 6.9. M. P. 1515°.	**Occurrence.** As chromite ($FeCr_2O_4$). **Preparation.** By reducing the oxide with aluminum. **Properties.** A steel gray, brittle and very hard metal. Stable in air, burns at high temperatures. Used in alloys and in chrome steel. Potassium dichromate, $K_2Cr_2O_7$, has many uses, in making pigments, in tanning and dyeing, and as an oxidizing agent.
Cobalt, Co. At. wt. 58.97. Va. II and III. S. G. 8.5. M. P. 1500°.	**Occurrence.** As smaltite, $CoAs_2$, and cobaltite, CoAsS. **Preparation.** Reducing the oxide with hydrogen. **Properties.** A white, magnetic, malleable metal. Its salts are pink. Used in Cobalt glass, which, when ground, gives the blue pigment, smalt.
Columbium, Cb. At. wt. 93.5. S. G. 12.7 M. P. 1950°.	A rare element. The metal is not affected by acids. It is weakly acidic and also weakly basic.
Copper, Cu. At. wt. 63.57. Va. I and II. S. G. 8.9. M. P. 1064°.	**Occurrence.** In oxide, carbonate and sulphide ores. **Preparation.** The oxide is reduced with carbon. It is refined by electrolysis. **Properties.** A red, lustrous, very ductile and malleable metal. The best electrical conductor next to silver. Dis-

CHEMICAL ELEMENTS — Continued

	solves readily in nitric acid, and in other acid when aided by oxygen. It is used for electrical conductors, for electroplating, as sheet copper, and in many alloys. The compounds are poisonous and are used in germicides, and insecticides. Blue vitriol is $CuSO_4 5H_2O$.
Dysprosium. **Erbium.** **Europium.**	Are rare earth elements, separated from other elements with great difficulty.
Fluorine, F. At. wt. 19. M. wt. 38. Va. I.	**Occurrence.** Mostly in cryolite, Na_3AlF_6, and fluorite, CaF_2. **Preparation.** Electrolysis of hydrogen fluoride in a special cell. **Properties.** A pale yellowish-green gas. The most violently active non-metallic element. Decomposes water, liberating oxygen as ozone. Hydrogen fluoride is used for etching glass and in the decompcsition of silicates.
Gadolinium, Gd.	A rare earth element, difficult to separate.
Gallium, Ga. At. wt. 69.9.	A rare element found in some zinc blende. Like aluminum the oxide is both acidic and basic.
Germanium, Ge. At. wt. 72.5.	A rare element, having the properties intermediate between silicon and tin.
Glucinum (or Beryllium). **Gl.** At. wt. 9.1. Va. II. S. G. 1.8.	**Occurrence.** In beryl. **Preparation.** Electrolysis of the fused double fluoride. **Properties.** A very light metal with the excellent qualities of aluminum to even a greater degree. But it is rare.
Gold, Au. At. wt. 197.2. Va. I and III. S. G. 19.32. M. P. 1062.4°.	**Occurrence.** Chiefly free, but also as telluride. **Preparation.** Gold bearing sands are washed, and the gold collected in mercury from which it is separated by distillation. When gold occurs in a very fine state it is dissolved from the powdered ore by cyanide. **Properties.** A very soft, brilliant, yellow metal, an excellent conductor, and the most ductile and malleable of all metals. It is very stable and insoluble in all acids, except aqua regia. It is both acidic and basic. Gold is alloyed with copper or silver to increase its hardness. The fineness of gold is expressed in carats, 24 carat gold is the pure metal.
Helium, He. At. wt. 3.99. M. wt. 3.99. B. P. 268.7°.	**Occurrence.** In air about one part per million by volume. In large quantities in the atmosphere of the sun. **Preparation.** Fractional distillation of liquid argon. The lightest substance next to hydrogen. Combines with no other elements, and has the lowest B. P. of any substance.
Hydrogen, H. At. wt. 1.008. M. wt. 2.016. Va. I. B. P.—252.5°.	**Occurrence.** 11.19% of all water, also in petroleum, natural gas, and all living organisms. **Preparation.** By electrolysis of water, and by the action of zinc and other metals upon several strong acids. **Properties.** The lightest known substance. It is readily absorbed by a number of metals, especially by palladium. Combines powerfully with oxygen, fluorine and chlorine. In water, acids, living organisms and organic compounds it plays a most important role. It is used for filling balloons and in the oxy-hydrogen blowpipe.
Indium, In. At. wt. 114.8.	A rare element, occurring in zinc blende. Its vapor colors a flame blue.
Iodine, I. At. wt. 126.92. Va. I, V and VII. S. G. 4.95. M. P. 114°.	**Occurrence.** In certain sea weeds, and in Chili saltpeter. **Preparation.** Treating iodides with chlorine. **Properties.** Dark gray crystals with metallic luster. Its vapor is violet. Slightly soluble in water, but readily in alcohol, ether, carbon disulphide, chloroform and solutions of potassium iodide. Combines with many elements, but with less energy than chlorine and bromine. It colors starch blue. Used in medicine and in many organic syntheses.
Iridium, Ir. At. wt. 193.1. S. G. 22.42. M. P. 1950°.	**Occurrence.** With platinum. **Properties.** A white and very hard metal. Not attacked by aqua regia or any acid. Used for hardening platinum.

CHEMICAL ELEMENTS — Continued

Iron, Fe.
At. wt. 55.85.
Va. II and III.
S. G. 7.86.
M. P. 1804°.

Occurrence. As the ores, magnetite, hematite, limonite, and siderite; also in pyrites and widely distributed through rocks and soils.

Preparation. In the blast furnace where the ores are reduced by carbon monoxide, and other matter is run into slag. The result is pig iron from which the different kinds of iron and steel are prepared. The essential difference in these is due to the varying proportions of carbon contained, and the influence of small amounts of other metals alloyed with steel. Mn., Ni., Cr., Mo., W., V., Ti., Si. and Cu., are all used to impart special properties to steel. The carbon content varies from 2% to 5% in cast iron; .2% to 1.5% in steel; and less than .2% in wrought iron.

Properties. A white, malleable, ductile and magnetic metal. It rusts in moist air, and dissolves readily in dilute acids. It is by far the most important metal in the extent and the varied applications of its usefulness. Some of its compounds are used in medicine, and green vitriol ($FeSO_4 7H_2O$) is used as a disinfectant, in dyeing and in the making of ink.

Krypton, Kr.
At. wt. 82.9.

Occurrence. In minute quantity in air.

Properties. Like argon, forms no chemical combinations.

Lanthanum, La.
At. wt. 139.0.
Va. III.

Occurrence. In the rare mineral lanthanite.

Properties. An iron gray metal, malleable and ductile. It is unstable, and reacts with water.

Lead, Pb.
At. wt. 207.1.
Va. II and IV.
S. G. 11.4.
M. P. 326°.

Occurrence. Principally as galena (PbS).

Preparation. Partial roasting of the ore, then continuing the heating in a closed furnace. The crude metal is then purified.

Properties. A soft, gray metal, malleable but of small ductility. It is stable in air, is but little affected by acids, excepting nitric acid. Heated in air it forms the oxide litharge (PbO) which oxidizes to red lead (Pb_3O_4) on further heating. It is used for water pipes, as sheet lead, lead foil, in shot, storage batteries, and in a number of important alloys. The basic carbonate, "white lead" is the most important basis of paints.

Lithium, Li.
At. wt. 6.94.
Va. I.
S. G. 0.53.

Occurrence. In some rare minerals, and in some mineral waters.

Preparation. By electrolysis of the fused chloride. A silver white, soft metal, that tarnishes quickly in air, decomposes water, and combines readily with nitrogen. The carbonate is used in medicine. Lithium salts color flames carmine red.

Magnesium, Mg.
At. wt. 24.32.
Va. II.
S. G. 1.75.
M. P. 633°.

Occurrence. Widely distributed in carbonates, as magnesite and dolomite, as sulphate, chloride, and in many silicate rocks.

Preparation. Electrolysis of fused carnallite.

Properties. A silver-white, tough metal, ductile when hot. It tarnishes in air, decomposes boiling water, is very active toward acids, and burns with an exceedingly dazzling bright light. The sulphate, "epsom salts," and the oxide and carbonate are used in medicine. Magnalium, the alloy with aluminum is light and strong and has important uses.

Manganese, Mn.
At. wt. 54.93.
Va. II, III, IV, VI and VII.
S. G. 8.0.

Occurrence. Principally pyrolusite (MnO_2), also as Mn_2O_3, and Mn_3O_4, and as a minor constituent in many rocks.

Preparation. Reducing Mn_3O_4 with aluminum filings.

Properties. A hard steel-gray metal. It rusts in moist air, and dissolves in dilute acids. Used in steel manufacture and in alloys. Potassium permanganate, $KMnO_4$, is an important oxidizing agent and disinfectant.

Mercury, Hg.
At. wt. 200.
Va. I and II.
S. G. 13.6.

Occurrence. Free and as cinnabar (HgS).

Preparation. By roasting cinnabar and distilling off the mercury. A silver-white liquid metal. It is stable in air and is dissolved by nitric acid, and aqua regia. Used in

CHEMICAL ELEMENTS — Continued

M. P.—39.5°. B. P. 356.95°.	many scientific instruments and in the extraction of gold from its ores. It forms alloys called amalgams with many metals. Its salts are poisonous, some are used in medicine and the bichloride as a powerful germicide.
Molybdenum, Mo. At. wt. 96. Va. III, IV, V and VI. S. G. 9.0. M. P. 2110°.	**Occurrence.** As molybdenite (MoS_2). **Preparation.** By reducing the oxide with aluminum. A white malleable metal, insoluble in dilute acids. It is used in steels.
Neodymium, Nd. At. wt. 144.3.	A rare element occurring with other rare earth elements.
Neon, Ne. At. wt. 20.2.	**Occurrence.** Along with argon, which it resembles in properties.
Nickel, Ni. At. wt. 58.68. Va. II and III. S. G. 8.9. M. P. 1385°.	**Occurrence.** In combination with arsenic and sulphur. **Preparation.** Reducing the oxalate in hydrogen. **Properties.** A white, hard, lustrous metal, malleable, ductile and tenacious. It is stable in air, but dissolves readily in nitric acid. Its salts are green. It is used in plating and in a number of important alloys.
Nitrogen, N. At. wt. 14.01. M. wt. 28. Va. III and IV. B. P.—194°.	**Occurrence.** Four-fifths of the atmosphere, also in ammonia, nitrates, all living organisms, and in many organic compounds. **Preparation.** Removing the other constituents of air, or by heating ammonium nitrite. **Properties.** A colorless, odorless gas, inactive, but though it is brought into combination with difficulty, its compounds are exceedingly numerous and important. The most common of the compounds are ammonia (NH_3), and nitric acid (HNO_3).
Osmium, Os. At. wt. 190.9. S. G. 22.48. M. P. 2400°.	**Occurrence.** Along with platinum. **Properties.** The heaviest known metal. It has the highest known valence of VIII, and its principle compound is the tetroxide (OsO_4).
Oxygen, O. At. wt. 16. M. wt. 32. Va. II. B. P.—184°.	**Occurrence.** Free in the air of which it forms one-fifth. It constitutes eight-ninths of water, and nearly fifty per cent of the earth. **Preparation.** By heating potassium chlorate, or barium dioxide. **Properties.** A colorless gas, but it is blue in deep layers, slightly heavier than air. It is soluble in water to the extent of three volumes in 100 of water. It is exceedingly active, and combines with nearly all elements. Its oxides form the basis of most of inorganic chemistry. Its uses in respiration and combustion are fundamental to life and civilization.
Palladium, Pd. At. wt. 106.7. S. G. 11.9. M. P. 1535°.	**Occurrence.** Along with platinum. **Properties.** Resembles silver and platinum. Dissolves in nitric acid. The metal may absorb up to 900 times its volume of hydrogen.
Phosphorus, P. At. wt. 31.04. Va. III and V.	**Occurrence.** As phosphates in apatite and other minerals, in small quantities in all soils. It constitutes the chief mineral matter of bones, and is a necessary constituent of the tissues. **Preparation.** Reducing calcium phosphate with carbon and sand in the electric furnace. **Properties.** Phosphorus exists in two forms: the yellow form which is waxy, dissolves in carbon disulphide, melts at 44°, ignites at a very low temperature, and burns with great energy. It is very poisonous. Red phosphorus is a crystalline powder, insoluble in carbon disulphide, acts with less energy and is non-poisonous. Phosphorus is used for the heads of matches, and the phosphates are important as fertilizers.
Platinum, Pt. At. wt. 195.2. Va. II and IV. S. G. 21.48. M. P. 1753°.	**Occurrence.** Free, alloyed with the other platinum metals. **Preparation.** The separation of the metals is complex. **Properties.** A silvery metal, tenacious, ductile and malleable. Resists all acids, but dissolves slowly in aqua regia. Because of this resistance and its high melting point it is in-

CHEMICAL ELEMENTS — Continued

valuable for chemical vessels. It also is the only metal that can be successfully fused into glass, hence its use in electric lamps.

Potassium, K.
At. wt. 39.1.
Va. I.
. G. 86.
M. P. 62.5°.

Occurrence. As chloride, sulphate, nitrate, feldspar, and many other silicates. It is a necessary constituent of soils, and of plants and animals.
Preparation. Electrolysis of fused potassium hydroxide.
Properties. A very soft, silver-white metal. It tarnishes instantly in moist air, and is one of the most active of the metals. Caustic potash (KOH) is the strongest base of available metals, and forms salts with all acids. These salts have various applications.

Praseodymium, Pr.
At wt. 140.6.

One of the rare earth elements, occurring with cerium and lanthanum.

Radium, Ra.
At. wt. 226.4.
Va. II.

Occurrence. In minute quantities along with uranium.
Preparation. The residues from uranium ores, after extracting the uranium, are treated so as to separate the radium and barium as bromides. These are then separated by fractional crystallization.
Properties. Radium in any form emits three kinds of rays, different from light. These pass through objects opaque to light, and affect photographic plates and phosphorescent screens. It has been used successfully in the treatment of cancer.

Rhodium, Rh.
At. wt. 102.9.

Occurrence. In platinum ores, and is of the general character of the platinum metals.

Rubidium, Rb.
At. wt. 85.45.
Va. I.
S. G. 1.52.

Occurrence. In minute amounts along with potassium salts, and it strongly resembles potassium in all its properties.

Ruthenium, Ru.
At. wt. 101.7.

Occurrence. In ores of platinum. Of the general character of the platinum metals, resembling especially osmium, and like it forms several oxides.

Samarium, Sa.
At. wt. 150.4.

A rare metal, resembling in general the rare earth elements in its properties.

Scandium, Sc.
At. wt. 44.1.

A typical rare earth element.

Selenium, Se.
At. wt. 79.2.
Va. II, IV and VI.

Occurrence. With sulphur and sulphides.
Preparation. Reducing selenious acid with sulphur dioxide.
Properties. The element occurs in three forms: the red amorphous, the red crystalliue, and the blue-gray metallic. The latter conducts electricity, and its conductivity is greatly increased by light. Therefore, it is used in cells for measuring light. Its chemical compounds resemble those of sulphur.

Silicon, Si.
At. wt. 28.3.
Va. IV.
M. P. 1200°.

Occurrence. Silicon dioxide (SiO_2) occurs in sand and different forms of quartz. Most of the earths crust is composed of silicates.
Preparation. Reducing sand by heating with magnesium powder. Amorphous silicon is a brown powder, that burns in air. Crystalline silicon forms black needles and is less active. Silicon is used in steel making. Some quartz and silicates are used as gems. Quartz sand is used in manufacturing glass. Silicon carbide (SiC) "Carborundum" is nearly as hard as the diamond and is used as an abrasive.

Silver, Ag.
At. wt. 107.88.
Va. I.
S. G. 10.53.
M. P. 960°.

Occurrence. Native and as sulphide, usually accompanying galena.
Preparation. Separated from lead by the Pattison or the Parkes process. Separated from gold by nitric acid.
Properties. A white, lustrous, tough, very ductile and malleable metal, the best conductor of heat and electricity.
It is not oxidized by air, but it is tarnished by hydrogen sulphide. It dissolves in dilute nitric and in boiling concentrated sulphuric acid. Uses, for coinage, and for many useful articles and ornaments. Silver nitrate is used as

CHEMICAL ELEMENTS — Continued

"lunar caustic" in cauterizing and to make the silver halides used in photography. Potassium silver cyanide, $KAg(Cn_2)$, is used in plating.

Sodium, Na.
At. wt. 23.0.
Va. I.
S. G. 0.97.
M. P. 95.6°.

Occurrence. As salt ($NaCl$), nitrate, borate, carbonate, and in many silicates.
Preparation. Electroylsis of the fused hydroxide or chloide.
Properties. A silver-white metal, soft as wax. It is very active, readily decomposes water and resembles potassium generally. Sodium hydroxide is a powerful base which forms salts with all acids. Most of these salts have their application.

Strontium, Sr.
At. wt. 87.63.
Va. II.
S. G. 2.55.

Occurrence. As carbonate and sulphate.
Preparation. Electrolysis of the fused chloride.
Properties. A light, active metal resembling calcium. It decomposes water vigorously. Its vapors color flames red, and it is therefore used for red fire in pyrotechny.

Sulphur, S.
At. wt. 32.07.
Va. II, IV and VI.
M. P. 114.5°.

Occurrence. Free and combined with metals as sulphides and sulphates.
Preparation. Melting the native sulphur and draining it off from the rocks and earth with which it is mixed. It is then purified by distillation.
Properties. It exists in two crystalline and one amorphous form. The rhombic form is the stable variety into which the others change on standing below 96°C. This variety is a brittle light yellow solid, soluble in carbon disulphid. It burns in air to sulphur dioxide (SO_2) and it combines with most metals to form sulphides. Sulphur is used for vulcanizing rubber, in gunpowder, fireworks and matches. SO_2 is used for bleaching, disinfecting and in the manufacture of sulphuric acid. The latter is the most important of all chemicals.

Tantalum, Ta.
At. wt. 181.
S. G. 16.6.
M. P.—2250°.

Occurrence. In rare minerals along with rare earth elements.
Preparation. Reduction of the fluoride by sodium.
Properties. A hard silver-white metal of great strength and stability. Used for filaments in electric lamps.

Tellurium, Te.
At. wt. 127.5°.
Va. II, IV and VI.

Occurrence. Free and as tellurides.
Preparation. Reduction of tellurious acid by sulphur dioxide.
Properties. Similar to those of sulphur and selenium, but is less acidic.

Terbium, Tb.
At. wt. 159.2. Va. III.

Occurrence. In rare earth minerals, and it has the general properties of these elements.

Thallium, Tl.
At. wt. 204.
Va. I and II.

Occurrence. In flue dust of sulphuric acid works. A bluish metal resembling lead, and has a rather high chemical activity.

Thorium, Th.
At. wt. 232.
Va. IV.

Occurrence. In monezite sand.
Preparation. By electrolysis. Welsbach mantles consist of 99% thorium dioxide.

Thulium, Tm.
At. wt. 168.5.

A rare earth element, associated with others of the group.

Tin, Sn.
At. wt. 119.
Va. II and IV.
S. G. 7.3.
M. P. 232°.

Occurrence. As cassiterite (SnO_2).
Preparation. Roasting the ore then reducing this by ignition with carbon.
Properties. A silver-white metal, rather soft, very malleable ductile and stable in air. It is used for tin plating iron and copper, and in a number of alloys.

Titanium, Ti.
At. wt. 48.1.
Va. II, III and IV.
M. P. 1850°.

Occurrence. As rutile (TiO_2) and titanic iron ore.
Preparation. Reducing the chloride with sodium.
Properties. A hard, brittle metal that can be forged at a low, red heat. It unites with oxygen and nitrogen when heated. It is used in steel manufacture.

Tungsten, W.
At. wt. 184.

Occurrence. As wolframite ($FeWO_4$) and as scheelite ($CaWO_4$).

CHEMICAL ELEMENTS — Continued

Va. II, IV, V and VI. S. G. 19.3. M. P. 2800°.	**Preparation.** Reduction of the trioxide by carbon at high temperatures. **Properties.** A hard, gray metal, burns in air and combines with chlorine at 250°. It is used in tungsten steel, and for filaments in incandescent lamps.
Uranium, U. At. wt. 238.5. Va. III, IV, V, and VI. S. G. 18.7.	**Occurrence.** As pitchblende (U_3O_8). **Preparation.** Reducing the oxide with aluminum. **Properties.** A white radio active metal, tarnishes in air and is fairly active.
Vanadium, V. At. wt. 51.06. Va. II, III, IV and V.	**Occurrence.** Rather rare, in vandinite, and accompanying other metals. **Preparation.** Reducing VCl_2 in hydrogen. **Properties.** A silver-white metal, stable in air, burns in oxygen, and combines with nitrogen when heated. It is used in special high grade steel.
Xenon, Xe. At. wt. 130.2.	The heaviest gas of the argon group, with the general group propeıties.
Ytterbium, Yb. At. wt. 172.	In rare earth minerals. A rare earth element.
Yttrium, Y. At. wt. 89.	A rare earth element, associated in rare minerals with other related elements.
Zinc, Zn. At. wt. 65.37. Va. II. S. G. 6.9. M. P. 419°.	**Occurrence.** As zinc blende (ZnS) principally, but also as carbonate, oxide and silicate. **Preparation.** Roasting the ore and reducing this with carbon. The zinc is distilled off. **Properties.** A bluish-white metal, brittle but malleable at 120°. It is rather active. It is used as sheet zinc and for galvanizing iron, in galvanic batteries, and in alloys. The oxide (zinc white) is a valuable constituent of paint.
Zirconium, Zr. At. wt. 90.6. Va. IV.	**Occurrence.** As zircon ($ZrSiO_4$). **Preparation.** Reducing the oxide with carbon in the electric furnace. A hard. gray metal, stable in air.

Definitions: A Chemical Element is a simple kind of matter, which cannot be resolved into two or more other substances by any chemical means. There are about eighty elements which combine to form the many thousands of substances found in the world.

The **Atomic Weights** are the unit weights of the elements which enter into chemical combination. They are based upon the atomic nature of matter. The elements are conceived to be made up of exceedingly minute particles or atoms, which for any given element have a definite characteristic weight. The atomic weight of Oxygen is represented by the number 16, and the relative weights of the atoms of other elements are expressed in comparison with this number.

The **Symbol** for an element stands for the name of the element and also represents its atomic weight.

A **Formula** stands for a substance and represents by symbols the elements which form it, and the proportions in which they are contained. e. g. CO_2 represents carbon dioxide, and shows that one atomic weight of carbon of 12 weight units is combined with two atomic weights of oxygen or 2 x 16 weight units. In other words it shows that 44 grams of the gas contain 12 grams of carbon and 32 grams of oxygen.

Electrolysis is the process of decomposing substances by means of the electric current. Many compound substances called electrolytes when dissolved in water or when in a molten condition, will conduct the electric current. But unlike a wire which suffers no chemical change from the passage of a current, electrolytes are decomposed by a current—the metallic part collecting on the negative pole and the non metallic part at the positive pole of the battery.

A GROUP OF PLANTS THAT CATCH INSECTS

1. Pitcher Plant
2. Sarracenia
3. Sundew
4. Huntsman's Horn
5. Butterwort
6. Venus' Fly-Trap

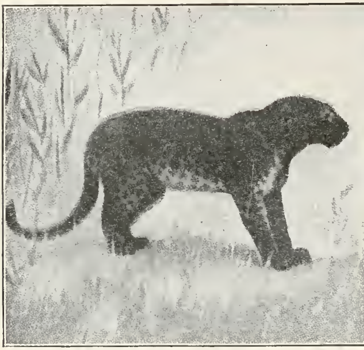
THE SPERM WHALE—THE TIGER OF THE DEEP

Possessed of amazing strength this monster of the seas sometimes turns upon the whalers. When this occurs at night, and it soars into the air made luminous by phosphorescence, it is like the extension of some gigantic flame cone from the deep.

BOOK OF NATURE

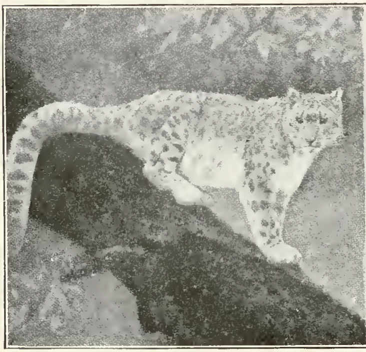
NATURE'S WONDERFUL FAMILY
WILD ANIMALS IN THEIR HOMES
BIRDS OF UNCOMMON BEAUTY
CHIEF OF THE HUNTING BIRDS
COMMON FARM AND ORCHARD BIRDS
WHAT HAPPENS IN A HIVE OF BEES
HOW INSECTS GUARD THEIR YOUNG
ANIMAL LIFE IN OCEAN DEPTHS
SOME INTELLIGENT PLANTS

MEMBERS OF THE NUMEROUS CAT FAMILY



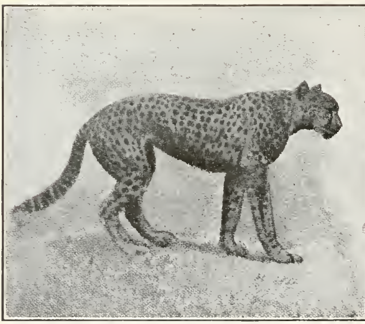
The wild leopard climbs trees, which lions and tigers do not. The leopard crouches on a bough and lies in wait to spring upon an animal passing underneath.

The lynx climbs trees and eats birds. It has wonderful eyes, and whenever we speak of anybody who seems to see everything we call him "lynx-eyed."

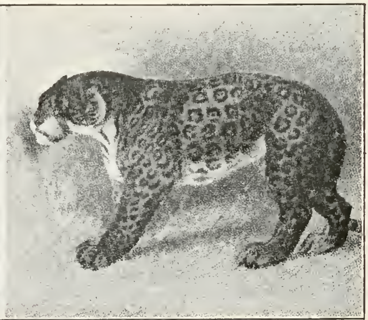


The snow leopard can live where it is very cold. It has a coat of warm light-colored fur, so that it can steal unseen over the snow and pounce upon its prey.

The puma, which people call the "American lion," kills cattle and horses, but never attacks a man unless the man attacks him first.



The cheetah is one of the few animals which, after being caught wild, can be made to serve man, and in India princes keep many cheetahs, to hunt antelopes.



The jaguar is a more terrible-looking beast than the leopard, having much thicker legs and a heavier head. Like the leopard, it has a spotted coat.

NATURE'S WONDERFUL FAMILY

Nature is the mother of us all. By Nature we really mean the whole of life—everything that is not made by man. But many natural things, such as the sun and moon and the earth itself, come into other parts of our book, and here we shall read of the two most important things in Nature—Animal Life and Plant Life. There were plants on the earth before the animals came, but it is better to begin with animals, and our book of Nature tells us first the story of the animals, and then the story of flowers and trees. We shall not tell our story with big words and strange names; but we shall learn all that we need know now about animals and flowers. Our story tells us of the wonderful things that live in the world with us, and the huge monsters that once lived upon earth and have now passed away.

WHEN we have interfered with the liberty of a busily-working honeybee or bumblebee, and have found to our sorrow that it can gallantly defend itself, we are quite inclined to wish that there were no such things as bees. But let us suppose that our wish could be suddenly granted. We know of course that we should have to do without honey, but how many of us know that, stranger still, we should soon lose many of our beautiful flowers as well as many of our more necessary fruits and grains? The strangest part of this, too, is that with all the work that it does for man, the bee is wholly unconscious that it is doing anything more than to supply its own needs.

A great many of our commonest blossoms contain a sweet juice, called nectar, which the bees love and need for their honey. They fly into the blossoms to drink the juice, and in doing so carry in with them from other plants a dust, called pollen, which the plants need in order to make their seed; if the flowers do not get this pollen they die. Among the plants to whose very existence the bee is necessary are the white clover, the red clover, several of the common violets, the roadside toadflax, and many another delightful blossom of our fields and lanes. If we are to do without the bees with their sharp stings we must make up our minds to do also without these plants that depend upon them for their support.

That is a little thing which wise men were a long time in learning. We ought always to remember it, because it shows how Nature has to plan so that the world may go on in the best way for us. When we think of the world, we think of a great place where men and women and children live. But the world was not made simply to be a home for men and women and children. If there were no living creatures but ourselves, there would be a great many empty places in the world. There would be a great deal of work left undone. There are places in the world where we cannot live.

But Nature does not like empty spaces. She must have living creatures everywhere, in earth and sky and sea.

Our eyes are not strong enough to see all the tiny things which live. If our eyes were as strong as the strongest magnifying glasses, we should see that the air we breathe is full of very tiny creatures. We should see that the soil in the garden swarms with little insects. We should see that the little drops of water which we drink have in them more living creatures than we can count. We know that there is life in the air as there is life in the sea. We can see the jellyfish floating on the top of the waves. We know that there are big fish and little fish beneath the surface. We know that there are monsters in the sea like whales and sharks, we know that deep down in the sea, deeper than the deepest mine in the world, there are creatures such as nobody has ever seen.

So there is life everywhere. Besides men and women and children, Nature has many workmen, great and small, to carry on the work of the world. Some are big, like elephants; some are so small that we cannot see them. Some fly in the air, some swim in the sea, some creep in the earth. Some live among us as our friends; some live wild in woods and mountains.

The great animal world

There have not always been the same sort of animals on the earth as now. Once upon a time, when there were no men and women and children on the earth, the only living creatures were strange and monstrous animals such as we see in our pictures. These huge creatures, bigger than any animals now alive, were the masters of the earth before man came. Some were so big that they could eat off the top branches of tall trees; some of the animals could fly and swim. The animals we know have come from these; through thousands and thousands of years the monsters were changing and passing away, until in their places we have the animals of our own time. Deep down in the rocks we find remains of the monsters still; sometimes when men dig deep down they come upon the whole body of an animal which must have died and been covered up when the rocks were being formed.

The wonderful way in which living things have changed

It has taken thousands of years to make the birds and animals the beautiful creatures that they now are.

The story of the animals makes us wonder if Nature tried all sorts of patterns before she made up her mind what sort of creatures should live in the seas and on the land. Once all creatures lived in the seas and rivers. Some lived in shells. Others were soft things like jelly, and had no backbones. These had all the sea to themselves for a very long time. But during this time they were growing into separate families, unlike those which had gone before. Proper fish began to swim about, and there were great sea-scorpions, as big as a tall man, and fishes with skins made like armor.

The reptiles, the flying dragons, the birds, and man

After these there grew up great creatures which could live in the water or out of the water, as the hippopotamus can today. Then came enormous reptiles. We have nothing living now like the reptiles which, by slow degrees, came into existence millions of years ago. Some of them had bodies as large as elephants, with heads like lizards, and huge teeth. Some could fly, and some could swim as well as they could walk. From some of the flying monsters came the birds, and still later came animals which, instead of scales and bony spines and great plates of bone, had hair to cover them. Little by little the animals changed, until they became the kind of creatures that are now living; and then, last of all, milleniums after the lower animals, came man.

Nature has been packing her box for millions of years

No man knows how much time passed away while all this was happening, but we know that at one time certain kinds of creatures lived on the earth or in the waters, and that after these came creatures of a different kind. There are no books to tell us these things, because there were no men alive to write books, but we find the bodies of these creatures deep down in the rocks today. When you unpack a box you begin at the top,

THE DEVELOPMENT OF THE ANIMAL KINGDOM

HOW THE ANIMALS CAME INTO THE WORLD

These pictures show us some of the strange creatures that have passed away, and help us to understand the story of animal life from the first thing we know about it. Once all creatures lived in the sea, and the first of all were only soft things like jelly, with no bones.

These creatures had the sea to themselves for a very long time, and slowly they grew into separate families, unlike those which had gone before. Proper fishes began to swim about, and some of them lived in shells. Then on the land great forests grew, and a new kind of animals came.

The first crocodile appeared now, but this age is important because great trees grew, drinking in the sunshine for thousands of years, and then fell, to be buried in the earth, and to lie there millions of years until they turned to coal. That is how coal began.

In the sea great fish lizards grew, four times as long as a man, some with necks like snakes. There were great sea-serpents, fish with skins almost like iron, and huge animals that could live either on land or sea.

Some of these creatures could fly and swim, and some could eat off tree-tops. The first birds came, and flying dragons. It has taken millions of years for these strange things to become the beautiful birds we know.

SOME OF THE GREAT MONSTERS OF THE PAST

On the land the great monsters were growing up, and the mastodon, like a giant elephant with four tusks, fought the savage tiger with teeth like swords. There were bats in those days, and a strange little animal which we may, perhaps, call the first horse, walked the earth.

The little sloths we see today have descended from creatures like that clasping a tree on the right of this picture. The giant sloth lived when the hippopotamus and elephant began, when there were horses with many toes and animals like tortoises bigger than a man.

Slowly the world grew into the kind of place it is today, and the animals became more like those we know. Bears lived in the caves, and the woolly rhinoceros and the savage hyena roamed the earth with the mammoth, like a giant elephant with long hair.

At last came man, the lord of all the animals. The first men lived in trees and caves, with the wild animals about them, and it has taken thousands of years for men to learn how to build houses, tame animals, make fires and write books to tell us what a wonderful place the world has been, and how much more wonderful still it is to be.

and you know that the things on the top were put last into the box, that those lower down were there before the top ones, and that the things at the bottom were put in first of all. Well, nature has been packing away things in her cellars for millions and millions of years. Her box is the solid rock. It was not always solid rock. It was mud and water. The water dried up, and as thousands of years passed away the mud grew harder and harder, so that it is now rock, almost as hard as iron.

How do we find the old-time animals in these rocks? They were born, and lived, and died, and were covered over. Floods carried them away to the seas and lakes, where mud came swirling down with the water from the rivers. The bodies sank and were covered with layer after layer of mud. As time passed away, nature dried up the seas and lakes, and, by pressure from within the earth, forced up the bed of the seas and lakes and rivers and made it dry land. The fishes and birds and other animals which had died and been buried in the mud were sealed up in this mass, and as the mud hardened into rock these creatures became part of the stone.

How we find the animals that lived long ago

When we dig deep down today we find mammals, birds, fishes, and even insects, many of them perfectly shaped, in the rock, where they have lain for millions of years. The mud which settled about them was so soft that it did not crush them out of shape. It preserved their shape, as it preserved the shape of the beautiful ferns printed in the coal. Some of the big things were just as carefully protected by the mud, without being turned to stone. Great animals like the mammoth, which was a sort of huge elephant covered with long hair, died thousands of years ago through sinking into deep mud in Siberia, and became frozen hard in that mud; and some of these have been found with flesh, and skin, and hair all preserved.

Of course, not all the creatures which were once alive have been preserved in this way. Many were destroyed in various ways after their death, but there still remains enough to show us what creatures of long ago were like, and to tell from what families those now on the earth first came. It seems very hard to believe that the birds, with their lovely plumage and their sweet song, came from ugly reptiles.

What the first of all birds looked like

The oldest bird known is called the archæopteryx. That is a Greek word, which really means "ancient wing." It was an extraordinary bird. It had a long tail, not all feathers as a bird's tail is now, but like a lizard's tail, long and thick, with bones and flesh, and with feathers growing from it. It had two legs, with which it could walk or perch in the trees, but it had two other limbs like hands, which it probably used to climb about the trees instead of flying from bough to bough, as birds now do. It had a curious eye fitted with a sort of armor shield as the reptiles have, and its beak was armed with great strong teeth.

Of course, there is no such bird as this now, and it is not surprising that such a bird should pass away. Even in these days two or three strange birds have died out. The dodo was quite common in the island of Mauritius 300 years ago, but there is not one alive today in all the world. It could not fly, because its wings were so small, and the dodo family was soon all killed. In New Zealand there used to be vast numbers of birds called moas, which were often 11 or 12 feet high. There still lives a bird called the apteryx, or kiwi, which, like the moa, the dodo, the ostrich and the penguin, cannot fly; but, though it is a fair-sized bird, it is tiny compared with the moa. The great auk, which used to come in thousands to the shores of Great Britain, is another bird which has died out within the last hundred years. There is not one in the world today, but there are a few of its egg shells, and they are so rare that men pay hundreds of dollars for them.

Men have killed many animals, but in making the world what it now is nature has killed far more. Whole races of animals have been destroyed by earthquakes and floods, by the sinking of land into sea, and by snow and frost and ice descending upon lands where before all was sunshine and rich vegetation. Then, again, great families of animals have gradually died out, and given place to others better able to fight the battle of life.

Think of the horse, that swift and beautiful creature. Once upon a time, long before man appeared on the earth, the horse was a miserable little thing with five toes on its front feet and three behind, and only as big as a fox. The horse has, through a long number of years, become larger and swifter and more beautiful, and its soft, spreading toes have become hard hoofs.

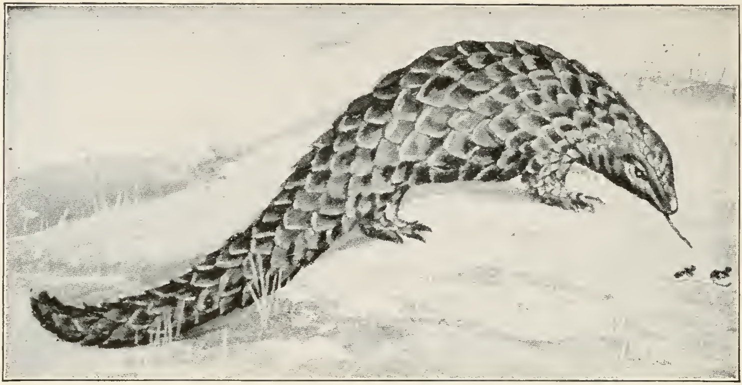
Think, again, of the humming bird, that tiny beauty, not much bigger than a good-sized bee, and remember that it, like all other birds, has descended from an herb-eating monster called the iguanodon, which had a great head like a lizard, a yard in length. It had a great tail and enormous hind legs, with shorter ones in front; and when it reared itself upon its hind legs the height of its head from the ground was 14 feet. In many ways it was like a bird. Its front legs, it is supposed, had first been used as paddles to help it to swim. As time passed these became changed into wings, with which it learned to fly.

There were others rather like it which ate flesh. One of these was a fearful creature called the megalosaurus, which fed upon the flesh of the great animals that lived on herbs. Another was called the brontosaurus, and a third was called the ceratosaurus. These monsters had bodies as big as the biggest elephants. Their legs were shaped like those of the iguanodon, except that the front legs were longer. The length of these creatures was as much as 60 feet; and their backs, when they were full grown, were quite 14 feet from the ground. All these creatures belonged to a family called the dinosaurs, which means terrible lizards.

The sea, as we have seen, had wonderful creatures in those far-off days. The waters teemed with what we now call the great fish lizards. One of these was the ichthyosaurus, which was 30 to 40 feet long. It had a wonderfully formed eye, which it could adjust so as to see things quite near or those far away. The remains of this creature are common in England, and scientists have been able to learn that though its home was chiefly in the water, it used to crawl to the land to bask in the sun, as turtles and seals still do. The ichthyosaurus has died out, but the shark lives as a relic of those bygone times. The whale is a much younger creature.

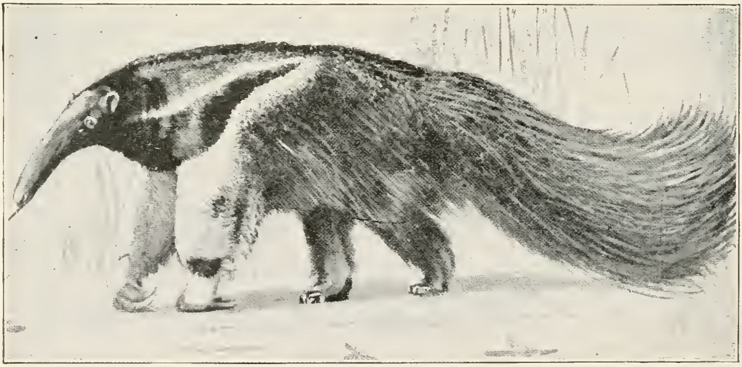
The sloths, small animals today, which cling to the branches of trees and live upside down, are descended from enormous creatures which, instead of having to climb the trees to eat the tender shoots, were powerful enough to pull the tree down to their mouths!

The bodies of these monsters were as big as elephants, and their front



The pangolin which is found in Asia and Africa is covered from head to tail with rough, hard scales, each scale being made up of tightly-woven hairs, all joined together. The pangolin lives in a burrow where it stays all day. It has a long, sticky tongue and feeds entirely on ants.

The aardvark is an African animal, and its curious name given by the Dutch means "earth-hog." It measures about five feet in length, and sleeps by day in a burrow, coming out at night to feed among the ant hills. Its long ears and pig-like head give it a strange appearance.



This ant eater is a big animal, four feet long, with an extraordinary tail about the same length. The body is covered with long, coarse hair, and the claws on its forefeet are so long and sharp that the foot has to be turned over on its side in walking. It has no teeth, but picks up the ants by its sticky tongue.

legs had enormous power. Similar to the great sloth was an animal called the mylodon, the remains of which have been found in a huge cave in Patagonia, along with the bones of other wild animals. In this cave there were also the bones of dogs and men, with bones made sharp by man to use, perhaps, as forks; and here also was found a quantity of cut grass, which makes us believe that once upon a time savages kept the mylodon alive in the cave and fed it with grass, just as we feed cows and horses today.

Nearly all these extinct monsters made their home at one time in Great Britain. In those days there was no sea between England and Europe.

These great animals, once upon a time, had the world to themselves. They were the masters of the earth. They disappeared in the ways we have seen, and in many other ways. Many of them were destroyed by the Great Ice Age, when the climate of a great part of the world was suddenly changed, and nearly all living creatures perished from cold.

All these things about the early world we learn from nature's own storehouses, the rocks and bogs or frozen wastes in which the strange monsters of land and sea fell and died. The great fish lizards are no more, the monstrous flying reptiles have gone. The gigantic birds are represented only by the ostrich and the emu. But there are still links with the puzzles of those old days. There is still a mammal—the bat—which flies; and there is still a mammal—the duckbill, or platypus—which lays eggs like a bird and has a beak like a duck. This duckbill lives in Australia, where that strange animal, the kangaroo, looking like some old-world freak, is also to be found. The great sloth has come down to very small size, though some people believe that there are still monstrous ones alive in Patagonia. The bats, with their wings and claws and mouse-like bodies, remind us of the curious things of old time, and the lizards and the armadillos tell us of a time when their ancestors were among the marvels of the world.

What is the use of all these animals? That is what we often ask ourselves. All things really have their uses. The humblest animals are able to teach human beings many lessons. A great man named Brunel wanted to make a tunnel under the Thames. It was quite a new thing which he had to do. And how do you think he got the idea for the work? He watched a little worm burrowing its way into wood, building round itself a case of slime which became hard and firm, and making a tunnel that could not fall in. And Brunel made his tunnel under the river just as the worm made its tunnel through the hard woodwork.

There is nothing more ugly at the Zoo than the alligators and crocodiles. They are cruel creatures, and have to be killed when we catch them, because, when they can, they eat men. Yet we cannot afford to lose them for they eat animals which would otherwise destroy the crops, and they help to dispose of the bodies of drowned animals that, if allowed to decay there, would poison the rivers and streams. The great hippopotamus, also, eats the things which grow in the rivers. If he did not the rivers would become choked with weeds, and boats would be unable to pass up and down.

So there is work for all. Man has his work; so has the elephant in the forest, the hippopotamus in the river, and the tiniest insect that hums in the air. Each does the work for which it is created and all help to keep the world healthy.

WILD ANIMALS IN THEIR HOMES

This story tells us of the life of the wild animals, and what happens in those parts of the world where the lion and the tiger still roam about and animals are the enemies of man. There are few dangerous wild animals left in America now, but there are still parts of the world where the lion is king and where its roar is terrible in the forest. Slowly, however, man has conquered the animal kingdom, and the great fight between animals and men ends always, and must end always, with the triumph of man. But we learn here that these animals are not useless in the world, for nothing ever created is quite useless, and the world could not spare even its wild animals.

THE best idea of peace in the world is that which we fancy we see when reading of the days to come when the lion shall lie down with the lamb, and a child shall lead them. We know that if a lamb lay down near a lion today, the lion would quickly eat it. The lion seems therefore, a cruel creature. But the lion is doing only what it was intended by nature to do. Suppose there had been no lions, or tigers, or leopards, or other flesh-eating beasts in wild countries. There would have been all kinds of deer and cattle, sheep and goats, hares and rabbits, and other animals which live upon vegetable matter, but there would have been nothing to keep their numbers in check. They would have multiplied to such an extent that the countries in which they lived could never have become the homes of men.

Nature never meant that any class of animals should become too numerous, because that brings trouble all around. It is said that the countries lying near the Mediterranean Sea lost their forests and vineyards through goats being allowed to work havoc. The goats, having no enemies to keep down their numbers, ate up everything they could. They gnawed the vines, they nibbled off the young shoots of trees; they ate the bark of the big trees and so killed them. They destroyed all the green growth upon the mountain-sides, and left a wilderness in place of smiling plenty. By so doing they caused the climate to become changed into one dry and unfavorable to the growth of green things. Where there are forests and green plains the air is never so hot and dry as where all is bare rock and sand. By destroying forests we ruin the climate.

Had the deer and cattle and sheep and goats all been allowed to increase as the goats in the Mediterranean countries were, there would have been far greater damage. The end of it would have been that these animals would have died of starvation, for they would have changed the beautiful places in which they lived into dreary deserts, where nothing would have been able to grow.

If the numbers of lions and tigers and other savage creatures had been allowed to increase without any check, these would in turn have become a deadly peril to us all. But man has become master of the lions and tigers. He is not so strong as these monsters, but he is wiser and has made spears and guns with which he can kill them. Wherever the white man makes his home, the lion and the tiger have to leave. There is no need now for lions and tigers to keep down the number of other wild creatures that eat herbs, for man can do that himself. He does not want big animals which kill his cattle as freely as they kill the creatures of the forest.

When the Lion Creeps Abroad in the Night

The story of the war between men and the savage beasts is as old as the

The elephant and the tiger are both monarchs of the jungle, each in his own sphere, but when they meet there is a fierce battle, and till the fight is over none can say who will be the victor. More often than not, however, the elephant is conqueror, and the tiger is fortunate if he can steal away from his enemy into the depths of the forest.

world; but victory always rests in the end with man.

There are lions in other parts of Asia as well as India, but Africa is now the chief home of the lion. Where white men have been living for a long time it is not very often seen, but when men are making their way into new parts, there the lion is a terrible enemy to them. The deer flee away at the sight of man, and the lion, unless he follows the deer, must have cattle, or even men, or else he must starve. So he attacks the horses, and mules, and cattle which draw the white men's wagons, and even kills and eats the men themselves. The teeth of the lion are of huge size, and its jaws are as strong as a great steel trap. How does it get the great power which enables it to kill a horse or an ox at a single blow?

THE THREE STRONGEST THINGS IN THE ANIMAL WORLD

Let us fancy that we are looking at those terrible front paws with which it strikes the blow. The leg, or forearm, as it is called, measures 19 inches around, and is made up of the hardest of hard bone, with muscle and tendons as strong as the strongest wire. The foot measures 8 inches across. When this foot strikes an animal the lion shoots out its terrible claws, which are hidden, when it walks, inside the joints of the toes. These claws are like great hooks made of yellow horn. They tear the flesh off an animal as we would strip the peel from an orange. The force with which these claws are driven in is almost more than we can believe. We are told that the three strongest things in the animal world are these: first, the blow from the tail of a whale, second, the kick of a giraffe, and third the blow from a lion's paw. The forearm of the lion is worked by great muscles at the shoulder, and the blow which it makes is really like the blow from a steam hammer. No wonder that it can kill a man or a big animal with ease.

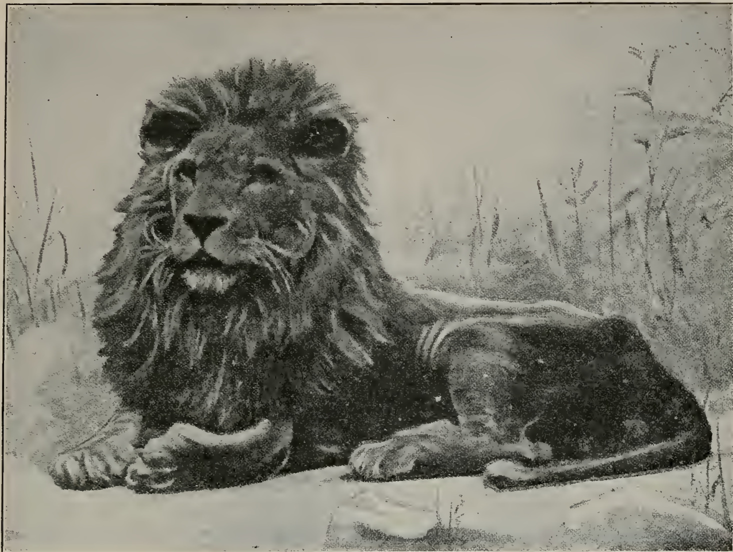
The lion and the tiger are the largest of the cat family. They are really great fierce cats. Your pet kitten is simply a young lion or tiger on a tiny scale. Notice the kitten's claws: they are made in the same way as the lion's. Notice how rough its tongue is upon your hand. The lion's tongue is like that, only much more rough. On it's tongue little hard points, like fragments of horn, stick up, so that with these the lion can tear pieces of meat from a bone just as if it were using a file.

THE LION'S ROAR IN THE FOREST AND HOW HE GETS HIS SUPPER

Another thing in which the lion is like the cat is that it cannot run fast for a long distance. It can spring a long way, and it can bound along at a great rate for a short time; but, just as a dog can race a cat, so a deer can easily race a lion. So the lion has to be very cunning to catch swift animals for its supper.

When the lion goes out to a pool to drink at night, he knows that other animals will be coming to the same spot. So he puts his great mouth to the ground and roars. There is no other sound in the animal world like the roar of a lion. It is so loud, so deep and so powerful, that it terrifies all the animals which hear it. It seems to send them wild with terror. The lion knows this, and he keeps on roaring. The result is that the animals which hear it forget everything in their terror; they rush madly to and fro, and one of them generally dashes straight into the mouth of the lion. That is one of his ways of catching a supper. There is another way.

Suppose that there are deer right out on the plain. It is of no use for the lion to go galloping out there, for



The lion is the king of beasts, the lord of the forest. A blow from a lion's paw is one of the strongest things in the world, like a blow from a steam-hammer. When he goes to drink at the pool at night, he puts his great mouth to the ground and roars, filling the other animals with terror, and sending them rushing madly to and fro in their confusion, often within reach of the lion's paws. That is how the lion gets his supper.

The tiger, which belongs to the same family as the lion and the cat, has not the grand head and mane of the lion, but it uses its strength just as surely as the lion, and in countries like India hundreds of people and thousands of cattle are killed by tigers every year. When they have once tasted human blood, tigers become very bold, and they will prowl round houses at night and carry off anybody they can catch.

the deer would see him and rush far away. There may be scattered rocks to enable him silently to creep from one to another, and so get near, ready to jump out. But suppose that there are no rocks; then he cannot get near. In that case two lions have to hunt together. One lies down and hides. The other lion goes quietly off in the reeds and bushes at the edge of the plain, until he can get round to the back of where the deer are feeding; then he dashes out with a roar. The deer rush away in terror, with the lion after them. Though he cannot keep up with them, he can keep near enough to drive them towards where the other lion is hiding. In an instant, when the deer draw near, this lion bounds forth, strikes right and left with his great paws, and at each stroke he kills a deer, and so gains a supper for himself and his friends.

The Sword-Toothed Tiger That Lived in England

The tiger is more to be feared, perhaps, than the lion. It does not live in Africa, but is to be found nearly all over Asia and especially in India. It is cunning and cruel; it will kill animals when it does not need food. It has not the grand head and mane of the lion, but it uses its strength just as surely.

Ages ago there were tigers more terrible even than those living today. They had two teeth which the tiger of today has not. These two teeth were great blades which grew down from the upper jaw. They were like sword blades, and the name given to that tiger is the "saber-toothed" tiger. It had legs bigger and stronger and claws more powerful than the tigers of today. With its great teeth and big mouth it could break the backs of huge beasts such as then lived.

How the Tiger Hunts His Prey

Animals are often colored like the scenes in which they live. The lion loves the open ground, so its fur has become a mixture between yellow and gray, like the sand and rocks. The tiger hunts in marshes or among long reeds and grass, so its coat is a fawn color with stripes of black, or a color almost black. When it crouches down among the reeds, or tall grass, it looks like the ground, with shadows of the reeds showing on it.

Although lions and tigers kill men and cattle, they do not do this all their lives. The lion likes deer and zebras and giraffes. The tiger eats deer and wild pigs and pea-fowl. When the tigers get old, or after they have been injured, it is less easy for them to catch wild prey, so they creep nearer to the homes of men, and take their cattle. The tiger does this very often in India. The poor natives who are set to guard the cattle are terribly frightened when they see a tiger, which, sometimes twice in a week, will carry off a cow. The man runs away, and so shows the lion or tiger that he is afraid. When it sees this, the animal strikes the man down.

THE TIGER PEERS OUT OF THE JUNGLE

Leopards Hide in Trees and Spring upon Their Victims

Leopards are more like tigers than lions, for they have no manes, but they

THE HYENA, GRIZZLY AND POLAR BEARS

The hyena is a fierce, ugly creature, which hunts in packs at night and steals everything it can get. It is a cowardly animal, with great power in its teeth.

This is a big grizzly bear, which climbs trees and will catch and kill a horse or a man. These bears generally live in a cave and sleep through the winter.

The Polar bear lives near the North Pole, at the very top of the world, where it is all ice and snow. It lives chiefly upon seals and walruses, but if it can it will kill and eat a man.

are spotted, instead of striped, as the tiger is. When wild, they are even more to be dreaded than the lion or the tiger, for they climb trees, which lions and tigers do not. They crouch down on a bough, and as a child or an animal passes underneath they spring down and kill it. The cruel leopard seems to love to kill simply for the sake of killing. The leopard is a most cunning animal. Though it will not attack a man who has a gun, it will spring on a poor native who is unarmed.

Some leopards can live where it is very cold. These are called snow leopards. They live high up in the mountains, where snow nearly always lies, and then their fur is long, to keep them warm, and light colored, so that they may steal unseen over the snow upon their prey. When captured and brought into a warmer climate, where there is no longer any snow about, the coat of the snow leopard often becomes darker.

The jaguar is a more terrible-looking beast than the leopard. It has much thicker legs, its head is heavier, and the spots upon its coat, instead of being round rings, like those of the leopard, are shaped like rosettes. Like the leopard, it climbs trees, and pounces down upon its victim. Its home is in America, from Texas south to Patagonia.

The Puma, the Enemy of the Dog and the Kind Man's Friend

Another of the big cats like the leopard is the puma, also called the mountain lion, panther and cougar. The puma can kill a horse or an ox, but of all things it best loves the flesh of the dog. It can be tamed, but you must not let it see a dog, for that will tempt it too much.

There is this to be said in favor of the puma: although he will fight the jaguar and the bear, and will kill cattle and horses, he never attacks a man unless he is himself first attacked. People sleep without any protection when they know that pumas are about, for they call him the kind man's friend.

How the Cheetah is Made to Hunt the Antelope

One of the few savage animals which, after being caught, can be made to serve man is the cheetah. If he is caught wild he can be taught to hunt for his master; but he cannot be made to do this if he has been born in captivity. Some princes in India keep cheetahs, just as many men in England keep packs of hounds for hunting foxes. When it has been trained, the cheetah is taken near to where there are deer or antelopes. At first its head is covered with a hood; when this is taken off the animal creeps away to where it sees the deer, and, springing upon one, catches it for its master. It is like the leopard, in appearance, having a spotted coat, but it cannot climb trees.

The weasel family is a big one. It includes the otter, which swims and dives splendidly and catches fish; the glutton, or wolverine, which lives in the cold countries and is a foe to the beaver; the stoat, or ermine, with its brown coat in summer and white coat in winter, and its everlasting appetite; and the weasel itself, which eats rats and mice and birds. If a weasel gets into a poultry yard, no chickens will be left alive.

The Little Sharp-Toothed Members of the Weasel Family

The pine marten is another of these little animals with long thin bodies. They are terrible little creatures, though they are so handsome. Some years ago a farmer in Ireland had fourteen out of twenty-one lambs killed, and the next night the other seven were served in the same way. When a search was made it was found that the whole of the damage had been done by two pine martens, which had made their home in the nest of a magpie in the top of a pine tree near by.

The American sable is sometimes called the pine marten, but is a member of a different family and is more like its cousins among the sables.

The most famous of the weasel family is the sable. This is a little animal which has a brown coat in summer, but a white one in winter when the snow comes. Its fur is so precious that men go into the cold, frozen wastes of Siberia to catch it, and in seeking it they have explored and made maps of lands where civilized men had never been before.

An animal known for its scent is the civet, which lives in Africa. Its scent is not unpleasant, but is valued, and the civet is kept tame, so that men can always get a supply of the scent. It is a waxy substance that is passed from the animal's body into a little pouch beneath the abdomen, from which it is removed by men who sell it to be used for making perfumes.

A little long-bodied animal which is much prized is the mongoose. Men tame it and have it about their houses, because it kills snakes and rats and mice. So long as it is kept under control, all goes well; but if it is not controlled, then woe betide its master. Many years ago the island of Jamaica swarmed with rats. These creatures ate the sugar-canes and ruined the planters. A number of mongooses were taken there from India, and turned loose in the fields. Though they quickly killed and ate the rats, they also killed all the useful little animals in the island.

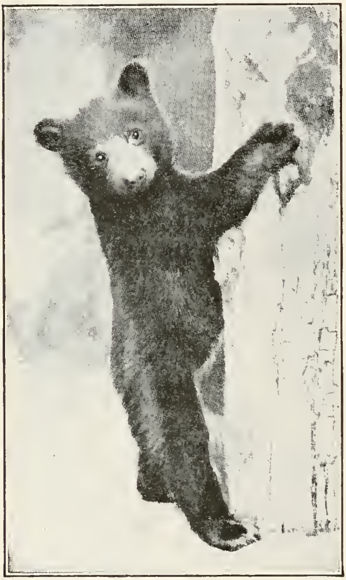
THE BEAR THAT LIVES IN A WORLD OF ICE AND SNOW

In the frozen Arctic regions the animal which men most dread is the Polar bear. It is not so fearful a bear as the one which used to live in Europe. That was called the cave bear, and was so big that two cave bears would have weighed more than three of the biggest bears in the world of today.

THE POLAR BEAR BEGS

The Polar bear lives chiefly upon seals and walruses, and on the flesh of whales, but if it can it will kill and eat a man.

In winter the female bear goes some distance away from the sea and lies down and buries herself in the snow. Then she goes to sleep for the whole winter, while her husband is out getting food and keeping himself warm as best he can. When she goes out in the spring from her snowy home, the she-bear generally takes a baby bear with her to show to her husband. The Polar bear can swim, and can make his way over smooth ice where no horse or



A LIVE TEDDY BEAR, THREE WEEKS OLD

man could go, since his great feet are covered with little hairs, which prevent him from slipping.

The Polar bear would perhaps not know what to do if he came to a tree; but the grizzly bear, or any other bear which does not live in the Polar regions, would know what to do. These would climb the tree if there were a bees' nest or a man at the top. Wherever there is food they will go. They will eat roots or berries; they will eat honey; they will catch and kill a horse or a man; they will eat the body of a man or an animal which has died. Nearly all the bears go to sleep in the winter. They get so fat in the summer that, while they are sleeping in the winter, they can live on the strength which is stored up in their fat. They are thin and hungry when they come out of their hiding-places in the spring. That hiding-place is generally a cave or some other hole, or it may even be the inside of a great hollow tree.

THE WOLVES THAT CHASE THE HORSES IN THE GREAT RUSSIAN WILDERNESS

The wolf is not as large an animal as the bear, but he is more to be feared. There are so many wolves, and they travel so fast and so far. They hunt together in large packs, and in the winter, when snow is on the ground and food is hard to find, they run for miles and miles to chase horses and men.

In Siberia and Russia, and other cold countries, wolves hunt men who are driving in sledges. No matter how quickly the frightened horses gallop, the wolf can keep up with them. Sometimes the driver is compelled to cut the harness of one of the horses and let it go, so that the wolves may seize that, and enable him to get safely away with the other horses. But if there are many wolves, some will still follow the man, and in the end run him down. If, while he is being chased, the man shoots a wolf, some will stop and eat the one which drops, but the others go on. When hunting animals they are just as determined. Two will hunt a deer as the lion does, one lying in hiding while the other drives the deer towards it. Wolves are found in many parts of the world, and used to live in such numbers in England and Scotland that the kings

The fox is the only wild animal left in the country which is at all like the wolf. It is handsome, cunning, and bold, and destroys the farmer's fowls and ducks.

The jackal runs like a shadow after the lion and tiger, and picks up whatever they leave. He will eat up anything the lion and tiger refuse.

This picture shows us a pack of wolves hunting for food. They hunt together in large numbers, and in the winter, when the ground is under snow and food is hard to find, they run for miles, chasing horses and men. Sometimes the driver has to let loose one horse to satisfy the wolves and to enable him to get away with the others.

made the people pay taxes, not in money, but in the skins of wolves. That was a sure way of making people hunt and kill the wolf.

The only wild animal left in the country now at all like a wolf is the fox, the animal which, in England, men on horseback hunt with hounds. It is a handsome but cruel animal. Like the leopard, it will kill all it possibly can. In one night it will kill scores of fowls, though it needs but one or two.

The cunning fox and the way in which he cheats his hunters

The fox lives in a hole burrowed in the ground, or in the root of an old tree. Sometimes it will share a burrow with a badger. The badger is a shy, handsome animal, with long, fine hair. No other animal of its size has such terrible jaws. The badger and the fox do not fight, or it would be bad for the fox. Sometimes they live together in a burrow which has two little rooms at the end. In one the mother fox rears her babies, and in the other the badger nurses hers. Although the fox does not bite so hard as the badger, its bite is dangerous, and men have gone mad from the wound caused in this way.

The fox is as bold as it is cunning, and, like the skunk, the fox has a strong smell, and wherever it goes it leaves traces of this odor. It is this which the dogs are able to follow. They can chase a fox which they cannot see. They do not look for the animal; they simply keep their noses to the ground, and follow wherever the scent leads them. The fox knows all about this, and does all he can to destroy the scent he leaves. He will swim as readily as a Polar bear, and he will make great leaps in the air as the hare does to break the track of scent.

The wild dogs, the wolves, the jackal, and the hyena

All dogs were wild once upon a time. The dogs and the wolves and the foxes and the wild dogs still living in places abroad all come from the same father and mother, far back in the ages. There are still to be seen in Achill Island, off the west coast of Ireland, dogs which are simply little wolves and nothing else. We need not be surprised, then, that the ways of wild dogs and wolves are alike. Wild dogs hunt just as the wolves do. They will attack any animal when they are hungry.

The jackal is really a smaller kind of wolf. He is a wretched creature, and runs like a shadow after the lion and the tiger. When the tiger has killed an animal and eaten as much as it wants, the jackals, which have been humbly creeping round about, rush out from their hiding place and devour the rest of the carcass. They eat up the filth of the villages; but they are great thieves, and dogs have to be kept to prevent them from doing still greater damage. They have a nose which is less pointed than that of the fox, but sharper than that of the ordinary wolf; and they have a tail like the fox.

If there is a more unpleasant animal than the jackal, it is the hyena. But, ugly and horrid as they are, they are important to the health of the countries where they live. If wounded animals get away and die in the forest, or if animals be left only partly eaten, their flesh, if allowed to lie in the sun, would become poisonous. But where hyenas are about, this thing never happens. They set out in packs at night, and clear up whatever dead bodies they can find, not even leaving the bones.

The home of the Weaver Birds

BIRDS OF UNCOMMON BEAUTY

WHEN Alice was in Wonderland, if she wanted suddenly to grow tall or to make herself smaller, all she had to do was to eat a piece of cake or mushroom, or drink something from a bottle, and she at once became the right size. When we think of birds becoming brilliantly colored, or marked like the surroundings in which they live, we think of Alice. But, of course, the case in real life is different from that in the story-book. No bird ever says to itself: "I will make my feathers the color of the rocks and sand in the desert, so that the hawks and eagles shall not see me." Nor does it make up its mind to wear rich and gorgeous plumage. The appearance of birds is brought about by long ages of change, by the slow working of natural laws.

Suppose we have a number of birds living in a place where they have many strong enemies. They cannot escape by fighting, for they are not strong enough. They cannot escape by flying, for their enemies fly faster. The probability is that they will be killed. But if some of the birds have feathers which enable them to appear, when hiding, like the rocks or sand, or like the trees or jungle, it is very likely that those birds will escape.

The birds which have not this advantage will be caught and killed, but the others will live, and the baby birds hatched from their eggs will be like them. It will become part of their nature to seek safety by hiding. Gradually they will become more and more like the scene in which they live. If the change of seasons brings great changes in the character of the foliage, the birds will be able to change their feathers so that they will keep pace, in appearance, with the altered looks of the things about their homes.

That is one way in which nature enables birds to flourish. But there is another way. It is the way of the female bird to mate herself to the handsomest among her suitors, like the princesses in the story-books; so that each generation of birds in this way tends to become stronger and more handsome. But the mother birds of gorgeous bird families are, as a rule, neither gay nor splendid, so that they may sit on the nest and hatch the eggs without danger of being molested by their enemies.

The most gorgeous birds in the world are the birds of paradise and the humming-birds. The first of these is, like the bower-birds, a distant cousin of our old friend the crow.

Only a naturalist could discover this. To anyone not acquainted with the science of natural history, it would be hard to imagine a greater contrast than that between the crow and the bird of paradise. But then the bird of paradise does not differ more from the crow than one species of bird of paradise differs from another species. There are nearly fifty different species of birds of paradise, and many of them may claim to be among the fairest of nature's children. Not only are they beautiful in coloring, but the arrangement of the feathers of some of them is really extraordinary.

The gorgeous plumage of the birds of paradise

There is one called the twelve-wired bird of paradise. It's tail is short and square, but there grow out twelve long, wire-like feathers, or bristles, for they are only the bare stems of feathers, which curve round towards the sides of the wings, and give the strangest appearance to the bird. The chief colors in its magnificent plumage are purple-bronze on the head, green and purple and black on the neck, bronze green on the back and shoulders, and emerald green to the edges of the outer wing feathers, with brilliant violet-purple to the rest of the wings and tail, and rich yellow on the breast. This bird is, including its two-inch beak, a foot in length. The long beak supplies the bird with food, which it takes in the form of honey from flowers.

There is a larger bird of paradise than this—the long-tailed one of the mountainous regions of New Guinea, which is over a yard in length. It is colored as richly as the other, but it adds a fan-like arrangement of feathers which rise from the sides of the breast, expanding at their outer ends in brilliant blue and green, while the tail feathers are of a lovely opal blue.

The king of the gay birds and its wonderful spray of feathers

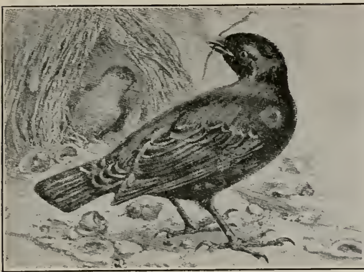
The king of gay birds is, however, the great paradise bird—a bird half the size of the long-tailed one, but lovely beyond description. The chief color of the body and wings is deep, rich brown, varied by tints of black and purple and violet. The top of the head and neck are colored like yellow plush, while from beneath the eyes and around the lower part of the throat run feathers of emerald green, from which spring deeper green feathers in a band across the forehead and chin. The beak is blue, and the feet are pink.

The most wonderful feature of this wonderful bird is a superb spray of feathers which it erects to cover itself and look its best. These feathers grow out from under each wing, rise into the air, and curve gracefully over in descending plumes, as much as two feet in length. The plumes are of a deep orange color, pale brown at the tip, and they cover the bird as with a cascade of glossy feathers.

When the male birds set out to win mates they gather together in the trees near the home, and dance and spread their feathers in the vainest way. On one of these trees, says Dr. Russel Wallace, who has studied them in their native home, a dozen or twenty magnificent male birds in full plumage may be seen together. They raise their wings, stretch out their necks and elevate their lovely plumes which they keep continually vibrating, so that the whole tree is filled with waving plumes in every variety of attitude and motion.

The bird with plumes like fans and a tail like a racket

We have been speaking of this one as the king of the birds of paradise, but the one that the naturalists call the king paradise bird is only about six inches in length, and is dis-



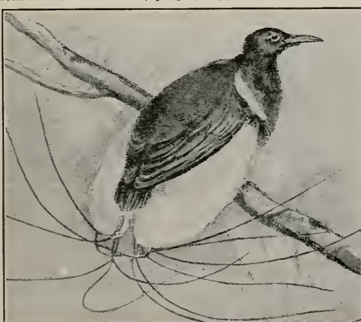
The satin bower-bird is a member of the crow family, is a great gardener and builder, and loves to build a bower beautiful with flowers and gay feathers.

Java sparrows are common in captivity. They have smart white feather collars in winter and spring. The Java sparrow is a type of the weaver-bird.

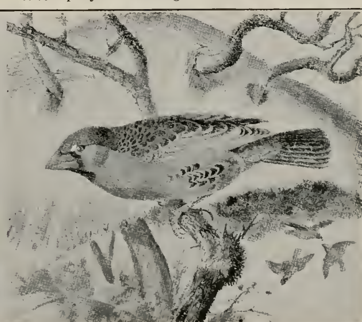
The gorget bird of paradise is lovely beyond description with its colors of black, purple, copper, green and gold.

The great bird of paradise is the biggest of its family, and has feathers like velvet, as well as the wonderful spreading tail. The colors in its plumage are gorgeous.

The humming bird, one of the loveliest of living things, flies so rapidly that its wings hum like those of a bee.



The twelve-wired bird of paradise has a tail unlike any other bird's. The shafts are bare like wires.



Hundreds of sociable weaver birds build nests together under one neat thatched roof made in a tree.

tinguished by two fan-like plumes on the breast, and a tail of curved feathers shaped at the end like a racket. Its feathers are green, purple, red and white.

Wilson's bird of paradise, another member of this family, named after its discoverer, is almost bare upon the head, over which two narrow tracts of feathers form a cross. The rest of the head is bare, and the skin a deep blue. From its tail grow out two long feathers, which cross, then curve completely, looking like the handles of a pair of scissors.

As we have a twelve-wired bird of paradise so we have also a six-plumed one. The plumes are long, glistening, wire-like growths, springing from the back of the head, and bare all the way up to the tips, where dainty webs of feather appear. This bird has a gorgeous ruffle, and a tuft of silver feathers upon the beak, which it can cause to lie flat or stand up at will. No pen could describe the glories of these birds. They must be seen. When the Zoo is fortunate, it has one or two alive, but they are hard to keep in captivity. We can give them the proper sort of food, for they like fruit and insects and seeds, but we cannot give them their native air, sunshine, and brilliant climate.

We have seen in earlier stories how birds and animals develop in a special way in particular parts of the world. The wonderful little humming-birds inhabit only the warm parts of United States, Brazil, Mexico, and certain mountain slopes of both North and South America. For beauty of plumage there is no bird to surpass them. They are as gorgeous as the birds of paradise, but not with the same stately grandeur, for the biggest of them are small, and the tiniest are no more than three inches from beak to tail. Yet they are most wonderful flying birds.

The conjurers rightly say that the quickness of the hand deceives the eye. Well, the humming-bird's quickness simply makes it impossible for the human eye to follow it. It is like the flash of shooting stars. A famous man who has often been near these birds in their native forests has told us how very difficult it is to see them. While he was watching a flower he suddenly saw something come between his eye and the bloom. It was a humming-bird, but it seemed like a gray blur as it paused for an instant before the flower. There was a look as of four black threads suspending it in the air. This would be the moving forks of the bird's tail. There was a gray film as, like lightning, the bird vibrated its wings; then, with a sharp twitter, it turned. There was a flash of emerald and sapphire light as the sun was reflected by its plumage, and in an instant it had vanished. It all happened so quickly that the word remained unspoken on the watcher's lips, the thought in his mind had scarcely had time to change. Yet in that time the bird had flown to the flower; it had thrust in its beak, shot out its long tongue, and sucked up the honey in the flower; and it had gone to a new flower which would furnish the next portion of its meal.

How the Humming-Bird Hangs in the Air Sipping Honey from a Flower

Everybody who has seen the humming-bird in its native wilds gives us the same impression of its marvelous swiftness. No one can see its wings move—they are vibrated too quickly. And it is because of the rate at which they move that the bird makes the humming sound which gives it its name. It lives all day in the air. It is never tired of flying, unless it be one of the few species which are more like other birds, and prefer, through weakness of wings, to take its food while perching. Most of the humming-birds feed when flying. This is, of course, the habit of many other birds—of the swallow and goat-sucker, for example—but the humming-bird has to hang in the air while sipping the honey from a flower. To do this it possesses wonderful wings for its size.

Birds are supposed to be unable to fly backwards, but the humming-bird is an exception. It can fly backwards for a little way. When it approaches a flower it inserts its long beak, while its body is raised higher than the flower. As it puts in its beak it lets its body sink down in the air, as if it were holding on to the flower by its beak. But it does not; its splendid little wings are working like steam-engines to keep it afloat in the air. When it has sipped such honey as the flower contains it raises its body again, withdraws its beak, and then flies out backwards, and darts away like a flash.

Some of the humming-birds can turn right round in the air with a single motion; some seem to dance in the air, while they can all dart from side to side in a manner such as to make the swallow, which they most resemble, seem slow and commonplace.

Five hundred kinds of humming-birds and their remarkable powers

When young, the humming-bird might pass for a strange sort of swallow, for its beak is blunt and wide like that of the young swallow. But as it grows older the beak gets longer and slenderer, until the full-grown bird has a bill ready to dip into the smallest flower to drink the honey which it stores. It does not depend wholly upon honey, though that is the chief part of its food. It eats a great many insects. In this respect it is a good friend to man. But it has another value: by going from flower to flower as it does it carries pollen from one to another, and does for those flowers what bees do for others, in making the plant fruitful.

There are nearly five hundred species of humming-birds, so it is hopeless for us to attempt any detailed description. The most remarkable part of their frame, after their splendid wings, is the long beak with its tongue capable of being shot out like that of the Old World chameleon. The tongue acts like a pump, and the beak is wonderfully constructed to help.

A humming hermit-bird of the forest, and a giant eight inches long

Among the most famous humming-birds is the Jamaican, which has two long feathers growing beyond its tail. far longer than the body of the bird. The hermit humming-bird, with its long beak and long tail, haunts the dark forest, eating insects, instead of seeking honey in the sunshine. The sword-bill, or siphon-bill, is the longest-beaked of all the humming-birds. Although the bird itself measures only four inches, the male bird has a beak four inches in length, while the female, still better provided, has a bill much longer than her body. The giant humming-bird is eight or more inches in length, and has wings measuring five or six inches across. It hovers over a flower like the smaller ones, but moves more slowly, and seems to gain support from its tail, which, while the bird is tapping a flower, opens and shuts like a fan.

The beauties of the humming-bird are well known. The racket-tailed has two long feathers from the tail, and two, like those at the back of the six-plumed paradise bird's head, bare but glistening to the tip, where the feather-web grows out in the shape of a racket. Then there are humming-birds with gorgeous crests and ruffs, humming-birds with balls of white feathers round their legs like powderpuffs, humming-birds with "boots" of white feathers, spangled humming-birds, humming-birds with snow-capped heads, with long beaks, with short beaks, with up-curving beaks, and beaks bending downwards like the scimitar of an Indian prince. We can never say that we have exhausted the beauties of birdland until we have seen these visions of splendor in their own homes. The sun-birds resemble them and are often called humming-birds, but belong to a different order.

We must turn back again for a moment to the crow family to make the acquaintance of the bower-birds. The males are a shining blue-black, except on the wings, where they are deep black. They are handsome, but they interest us chiefly from their love of beauty. They make their nest like ordinary birds, but they build avenues of twigs and houses or bowers to play in. Here the two sexes meet. The male birds show themselves off and the females are wooed and won by the best among them. But while the wooing is in progress the bower is a wonderful place. Sometimes it is several feet high, made of twigs and elaborately decorated. The gay feathers which other birds have dropped, pieces of colored cloth that they can pick up near men's homes, bleached bones, even bright tools, they build into the bower. But, prettiest of all, they bite off orchids and other beautiful flowers growing wild near them, and weave them into the decorations. The flowers fade of course, but the dead ones are taken out each day and thrown behind the bower, while fresh flowers are put in their place. There are different sorts of bower-birds, but in all the habit of building bowers is the same. One of them, the Papuan bird, makes a hut, two feet high, at the foot of a tree, roofs it with moss, and builds a gallery round it.

Among the birds remarkable for their nests are the weavers, or weaver birds. They form a large family, some of them very beautiful, as the whidah bird. The sociable weavers are even more ingenious builders than the bower-birds. They collect vegetable fibers and weave them round the branch of a tree. This forms the thatch, or roof of the dwelling. Underneath they make a great number of nests, where as many as three hundred birds may have their homes, all under the same roof. There they dwell together in peace, each pair of birds having their own nest and rearing their little ones.

THE WEAVER-BIRDS AND THEIR NESTS, AND THE LITTLE JAVA SPARROWS

In the following year they make new nests. These they join on to the layers of nests made in the previous year. To do so they have to make the roof bigger, and in course of time as layer after layer of nests is added the huge structure looks like a thatched cottage. Finally it becomes so heavy that it breaks the bough of the tree upon which it is placed, and a fresh start on another branch or tree has to be made.

The Java sparrow, a favorite bird in our aviaries, is a type of weaver-bird.

THE LYRE-BIRD AND THE PEACOCK, THE BIRDS WITH BEAUTIFUL TAILS

The Java sparrows are not as gorgeous as their distant cousin, the whidah bird, but they are still handsome and interesting. The white feathers on their cheeks disappear as summer advances, and the cheeks, neck and head are an unbroken black.

Now we come to another of the big beauties, the lyre-bird. It has a strikingly beautiful tail, shaped like the musical instrument called the lyre. Only the male bird has this, and not until he is four years old.

SOME BEAUTY BIRDS OF FOREIGN LANDS

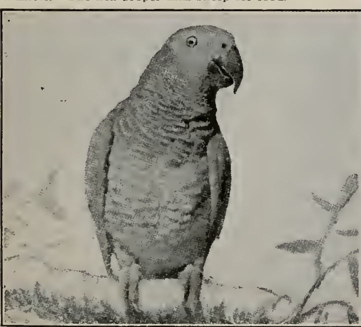
Hornbills live in Africa and India. Kaffirs in time of drought kill a hornbill as an offering for rain.

The toucan, which we see here, has an enormous bill, but this is honeycombed with air-cells to make it light.

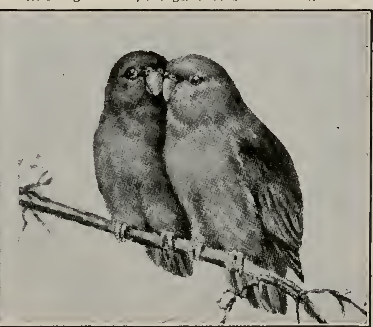
The laughing jackass of Australia is, as we see here, really a kingfisher. It loves to mimic the human voice.

The kaka parrot is a member of the kea family, but harmless. The kea proper kills sheep for food.

Australia's beautiful lyre-bird is closely related to our little English wren, though it looks so different.



The gray parrot of West Africa is a wonderful mimic. It can imitate birds and beasts, whistle a song, mock street criers, and imitate the sound of machinery.



Love-birds belong to the parrot family, and though their home is in Africa, they thrive in captivity and make amusing little companions.

The lyre-bird has a gift for imitating the songs and cries of other birds. In that he has a decided advantage over that most famous tailed domestic bird, the peacock. Among the birds frequently seen in pictures and well known in parks and gardens is the peacock.

No other bird has more perfectly colored plumage, but in spite of that the peacock is a disagreeable bird, with a hoarse screech for its call, which can be heard far and near.

It is well for him that he is such a beauty in appearance, or the peacock would never be tolerated in private life. When the courting season is over, his fine feathers disappear, and he slinks away until new ones grow. Then he comes out again in all his glory, proud as only a peacock knows how to be.

The strange toucan, and the hornbill which brings up its young in prison

With all their splendor, some of the beauty birds, it must be admitted, are to be regarded as a little freakish, and some of them are not all that could be desired in their ways. Among the strange birds let us take first the handsome but queer toucan and the hornbill.

The toucan is a bird with a huge beak like a small pelican's, but not soft like that great fisherman's bag-net. It is notched like a saw, and as it is brightly colored it gives the bird the strangest appearance. This beak is not so heavy as it looks, for it contains air-sacs which make it light. The hornbills share this advantage. They have big bills, with helmets of horn on the top, and these are lightened in the same way.

The hornbills are famous for a curious habit. When the female has laid her eggs in a hollow tree, the male makes a prisoner of her by plastering up the entrance, leaving only a small slit through which he can pass food for her and the young ones. She seems to assist in this. He does not let her and the family come out until the young ones are nearly full grown. The male bird, having to find the food, is worn almost to a skeleton during this long time.

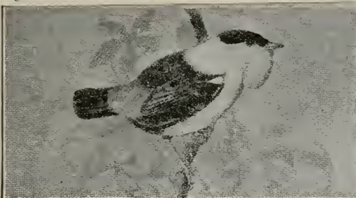
The king of the handsome climbers is undoubtedly the parrot. We cannot stay here to glance at the whole tribe, for when we sort out the many forms of parrots, macaws, love-birds, and cockatoos, there are hundreds of species to deal with. The handsome little parrakeet which is often seen in captivity has its home in Australia and the southern states. The gray parrot is a native of West Africa. Macaws come mainly from the warm parts of America and from India. When wild the birds all eat fruit and seeds. One species, however, the kea, has become a flesh-eating bird. This is one of the few instances of a bird's nature changing while actually under the observation of man. Nobody knows for certain what has caused it to change, but the kea has become a deadly enemy of the sheep-farmer in New Zealand. Its food had always been insects and fruit. One day a kea was found standing on the body of a dead sheep, tearing away at the wool. Such a thing had never before been known to happen. Ever since then the kea has been a bird of prey. The change could not have come as suddenly as that; the attacks of the kea must have been made before, but it had never been observed. Now two or three keas attack a sheep together, and by means of their long, cruel beaks they kill it.

The laughing bird that mocks a man in the Australian wilds

While we are thinking of Australasian birds, we must not forget the

STRANGE BIRDS WITH STRANGE FEATHERS

The waxwing has many of its feathers tipped with red or yellow and does not get its fine feathers till grown.



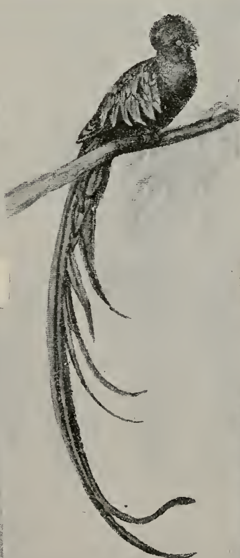
The manakin is brilliantly colored with a feather beard. The beating of its wings in flight sounds like a spinning wheel.

The bell-bird has a note like a bell. When many are calling the sound of note following note is like the beating of hammers on steel anvils.

The night-jar flies in the dark swiftly as a swallow.

The umbrella bird is one of the biggest of the chatterers.

The cock of the rock is a brilliant orange red and crested to the tip of the beak.



The quetzal is from Central America. Its feathers keep their lovely color after the bird's death.

The banded cotinga is a Brazilian bird which lives among the tree tops, only descending to feed.

laughing jackass, or laughing kingfisher. This is a bird which could beat the parrot, or even the famous Indian starling—called the mina—at laughing. Parrots and minas marvelously imitate human speech. Although they seem very wise birds they do not understand what they are saying. The mewing of a cat, which they imitate perfectly, has no more meaning for them than a song which they may learn to sing. So the laughter of the laughing jackass has no meaning for the bird. It has a voice, and uses it in this way. It follows a man in the wilds where there are trees, and perches near him, chuckling and laughing.

The beautiful kingfisher and the bird with a note like a bell

The kingfisher is a beautiful bird, which at one time was very scarce, owing to thoughtless women wearing its plumage in their hats. It flies like a swallow over the water, then, when it sees a fish, dives down like a flash. Some of the kingfishers are said to build their nests of the bones of fish which they have eaten. The kingfisher is one of the handsomest and most interesting of all birds.

We find more strange beauties among the family of birds called chatterers. The most striking is the umbrella-bird. This has a fine crest upon its head, and though the sides of its neck are naked, it possesses a lovely lappet composed of loose feathers hanging from beneath the throat. When it desires to call its mate, it raises its crest, moves its lappet in stately fashion, and pipes loudly. A more remarkable piping bird is known as the bell-bird. There are four species of this bird, of which the most famous is a pure glossy white. Its call is like the note, clear and melodious, of a beautiful bell. Sometimes it utters only one note, then rests. At other times it utters several notes, which then sound like a blacksmith playing on his anvil with a hammer. When several of the birds call and answer, the effect is beautiful.

The strange song of the manakin and the ways of the hoopoe

In the same family are the manakins, marvelously-colored little birds; and the cotingas, nearly related to the bell-birds, but far more brilliant in plumage. The manakin has a strange little song, which he utters when courting. He dances, too, in the funniest way, as if trying to show how much more agile he is than his fellows. Two rivals meet on the bough of a tree, sing their song and leap into the air, each in turn, always rising to the same height and always descending upon the exact spot from which they rose. But if they discover that they are watched by enemies, they disappear with remarkable speed.

They have a rival in the hoopoe. It is of a rich russet hue, with a beautiful crest upon the head and with wings marked out in black and white.

The cock-of-the-rock, the black-headed nun, and the tiny trogon

Returning to the chatterers, we must notice the brilliantly-colored cock-of-the-rock, famous for the great crest which hides its nostrils, and the resplendent orange plumage, for the sake of which the unfortunate bird is mercilessly shot. The cock-of-the-rock is a handsome bird, with its crest and gay plumage. When perched at the top of the high trees in which it makes its home, it gambols and plays and mews like a cat. There is another bird, a little one, the black-headed nun, which mews, too, but like a tiny kitten. Another gaudy-crested bird is the trogon, of which a Central American species, called the quetzal, is distinguished by a long streaming tail, which seems to help rather than hinder its strong and rapid flight.

COLONY OF FLAMINGOES IN THE BAHAMAS

The flamingoes are near relatives of ducks and geese. Their plumage assumes a rosy tint, deepening into scarlet-crimson on the wings. In the commonest species this tint virtually becomes scarlet over the entire body.

CHIEF OF THE HUNTING BIRDS

THE air has its lions and tigers —not real lions and tigers, but birds, which, in their way, are as fierce and hungry as the great four-footed animals of the jungle and the plain. When we study their lives, we can see that the eagles, the falcons, the kites, the buzzards, the vultures, the owls, and other flesh-eating birds, play a similar part to that played by the flesh-eating animals. Some strike down their prey, kill and eat it; others wait until the death of an animal or a man has taken place before they begin their meal.

First in the scale of splendor among the hunting birds comes the eagle, the most noble looking of birds that fly. It is the king of the falcon family, which includes no fewer than 300 species of birds that hunt their prey by day. Here for the moment we will keep to the eagles proper, and glance at some of the most important.

The largest are the sea eagles. Of these there are several species, scattered over a great part of the world. They are to be found in Scotland and the northern islands, and in wild parts of Ireland. One was caught in Windsor Forest, England, in 1856, measuring eight feet across the wings and three feet two inches from the point of the beak to the tip of the tail, and weighing twenty-two pounds.

The golden eagle, the handsomest of the family, inhabits Scotland and America. It is the largest of all save the Steller sea eagle. The golden eagle does not hunt in the sea, but otherwise its habits do not differ much from the habits of the sea eagle.

WHERE THE GOLDEN EAGLE BUILDS ITS NEST AND MAKES ITS LARDER

Like most other birds of prey, the female golden eagle is larger than the male. Her length, from the tip of beak to the end of tail, is about a yard; while the male eagle is several inches less. The plumage is rich and handsome. While the colors may differ, the majority of these birds have feathers of a golden-brown hue. The golden color occurs near the tips of the feathers, and gives a golden appearance to the whole. The bird builds in high, rocky places far from the haunts of men, and the rough, strong nest cannot be reached except by a rope let down from above.

Eagles are watchful parents. They will fiercely attack anyone who attempts to approach the nest in which their young ones are. The little eagles have big appetites, and the parent birds have to maintain quite a larder for them. The larder is generally a large rock near the nest, so that the eaglets can go to it and feed while the parent birds are away. Here on this stone hares and rabbits and birds are placed, and these the eaglets eat at their leisure.

If the little eagles need so much food, what do the big eagles require? They have hearty appetites to support their weight and flying powers.

THE STORY THAT THE EAGLE CARRIES OFF CHILDREN IS NOT TRUE

A golden eagle will eat in the course of a day a couple of partridges or a rabbit. It can live on that, but, like other creatures, it prefers variety in its food. These eagles will sometimes willingly eat putrid flesh as a change from their ordinary diet; and men, knowing this, set traps and catch them as if they were the silliest birds. But the desire for change does not end here. The eagles carry off lambs to their nests, and they attack and kill deer. It has been told a thousand times that eagles carry off children; but though we know for a fact that they will attack children guarding flocks which the eagles desire to rob, there is no proof that children ever have been carried away by these birds.

As to their attacking deer, there is no such doubt. They set about their work with as much method and skill as if it were part of their everyday life. Generally they will attack a young deer, that being more easy to kill. They drop from the sky like a flash upon the back of the deer they mean to secure. If they can, they drive it from its mother. The faithful hind, if she can keep her little one close beside her, will fight the great eagle with splendid courage, and striking out with her front feet, may beat it off. But if the fawn can be driven away from the hind, the hind becomes so alarmed that she seems unable to act, and in that case the eagle will send the little deer racing away in terror and kill it with its terrible talons and beak.

How the Eagle Will Terrify a Herd of Deer to Catch Its Prey

If this plan cannot be tried, the eagle does a still more amazing thing.

It will hover over a herd and frighten them into running away. Just as they are bounding round some narrow path which winds round the top of a precipice, the bird will swoop down upon the back of the deer, and drive home its great claws. The deer in terror seeks to throw off its foe, and generally jumps down the precipice, so killing itself and affording the eagle a meal without further trouble. That is just what the eagle wants, and it is for that reason that it makes its attack when the deer are in so perilous a place.

The only chance for a young deer when so attacked is to bolt into a narrow division between the rocks. There the eagle is practically powerless, for, seeing that its wings, when outspread, measure from eight feet to ten feet across, of course it cannot fly in a little space, and it will not venture in on foot. Eagles have been seen to suffer defeat in this way. But they do not, as a rule, lose their prey.

A noted huntsman saw a remarkable sight in a forest showing how the eagle can hunt. While he was stalking a herd of deer, he saw through his telescope that the animals became suddenly alarmed. He knew he had not caused their fright, for he was too far away. Suddenly a great eagle swooped into sight and attacked one of the small stags. Its plan was to drive it away from the rest of the herd, so that they could not help it. The bird did not attack with beak or talons, but kept striking the stag heavy blows on the back with the middle joint of his powerful wings. Several times it seemed as if he would fail to get the stag away, for the bird kept rising into the air as if to fly away. But each time he returned with more determination, and at last he did get the stag away from the rest of the herd and killed it. The man who had gone out to kill a deer by the aid of a gun saw his victim taken before his eyes by one of the hunters of the air.

An Eagle's Game of Dropping and Catching in the Clouds

The sight of the eagle, so keen and powerful, is the gift of nature; but its ability to catch things, though inherited, is developed by practice. An eagle has been seen to snatch up a wounded grouse as it fell through the air after being shot. Another swooped down and caught a rabbit which was being chased by hounds. The young eagle practices to enable it to do things of this sort.

One of these birds was seen to catch a rabbit. Away it went with the rabbit, up into the sky. Then, when far up, it let the rabbit drop from its talons. While the rabbit was dropping through the air, the eagle descended upon it, and caught it. Then it carried it up again, and once more let it drop, and again caught it. This it repeated several times, never once failing to catch the rabbit as it was falling through the air. The young eagle was at play, but it was practicing for the serious business of life. Very wonderful it is that a bird should be able to give a heavy thing like a rabbit a good start in a fall through the air towards the earth, then catch it up and secure it.

The wonderful love of a free eagle for its trapped comrade

Fierce as the eagle is, it is affectionate to its kind. A strange example of this was afforded in a forest, where a beautiful golden eagle was found dead in a trap which had been set to catch a fox. The bird had espied the bait afar off, and, going down to get it, had been seized by the trap and left to die a miserable death. The strange thing was that the eagle had not died of starvation, nor from any serious injury. It was caught only by one claw. Apparently the knowledge that it was a prisoner had killed it, for there was abundant food beside it. Other eagles, seeing the prisoner in the trap, had brought it food. There, beside the dead eagle, were two grouse, and a rabbit, still warm when the hunters came to the trap.

The osprey that catches fishes, and its foe, the bald eagle

The affection which the eagles show reminds us of the osprey, which, though as wild as the other members of its family, displays great love for its mate and children. It is a handsome bird, living almost entirely on fish, and for that reason is called the fishing hawk. It is about twenty-two inches in length, but its fine wings measure five feet six inches across, and on these it sails in graceful flight over the sea in which its food is to be found. In Scotland the osprey has an enemy in the sea eagle, which will occasionally rob it of the fish it has caught. In North America the bird the osprey most dreads is the great white-headed eagle, the bird, which, because of its white crown, is called the bald eagle. This is a bird which will eat pretty nearly anything. Though fond of fish, it is no fisherman. so it robs the osprey as it is returning to its nest with a fish in its talons. But the white-headed eagle will eat dead horses or other animals, and it may be seen seated on such a carcass feasting and angrily keeping off a flock of vultures which prowl round, hungry, yet afraid, like jackals creeping about an animal on which a lion is feeding.

The vulture that drops a tortoise from a height to split its shell

It is impossible to be fond of a vulture, valuable as its work often is when it plays the scavenger.

There are two kinds of vultures that are less horrid than the others. The splendid lammergeier, or lammergeyer, which soars above the Italian Alps, the Caucasus, and the hills of Spain, is not so repulsive a creature as the ordinary vulture. The average vulture has dirty, dusky-looking plumage, and its neck is bare, with the discolored flesh showing plainly. The lammergeier is feathered to the beak, and sails in the air with the grace of a yacht.

Its claws are not especially strong enough to enable it to carry off a child, and it attacks only what it can eat. Sometimes it will take a live animal, but generally speaking, its food consists of the flesh of animals which have died. In India, where it is very abundant, it haunts slaughter-houses and the soldiers' quarters, on the lookout for scraps, and particularly for bones. These it carries to a height, then drops them on the rocks to split them. It does the same with tortoises.

THE MIGHTY CONDOR THAT SEEMS TO BE ASLEEP ABOVE THE MOUNTAIN TOPS

The biggest of all the vultures is the condor, the huge, heavy bird which makes its home in the Andes of Peru and Chile. The male bird is about four feet in length, and its wing-spread is from eight to eleven feet or more. The male bird has a large, fleshy wattle, which forms a crest to the head.

Both male and female have powerful beaks, but their claws, while they help in tearing their food, have not power enough to enable them to carry away heavy bodies. Their food consists chiefly of animals of the mountain-side and the plain, which have either died a natural death or been killed by wild animals.

The condor has marvelous eyesight, and, though it sails high up in the air so smoothly that men have believed it to be asleep while thus flying, hunters say that it is closely watching some animal on the plain thousands of feet below, which is being killed or is near death from disease. Suddenly the bird drops like a stone through the air. Others from all quarters follow; and hunters see a carcass swarming with birds which a moment before had been specks in the sky.

The condor has this trait in common with the other vultures, it can fast for several days, but to make up for this it gorges itself when it gets the chance. This accounts for the fact that cattlemen are able to catch it with ropes. It seems unlikely that they should lasso a grand flyer like the condor, but the bird so fills itself with food that it cannot rise into the air swiftly enough to avoid the noose which the expert cattleman throws.

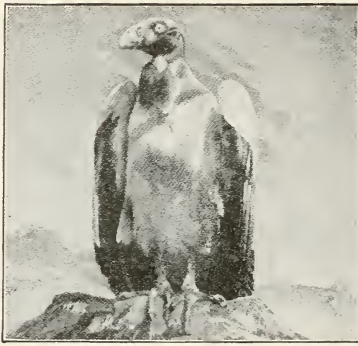
THE POWERFUL WEAPONS WITH WHICH THE WINGED SCAVENGERS ARE ARMED

But the true vultures are greedier than even the condor. One, an Egyptian vulture, has been seen to gorge itself to such an extent that it could not move, but lay on its side and still fed. There are many kinds of vultures, some worse than others. They share with the hyenas and jackals and wild dogs the filth of the villages of the East. They eat also all the putrid flesh of dead animals, and kill lambs that are too feeble to defend themselves.

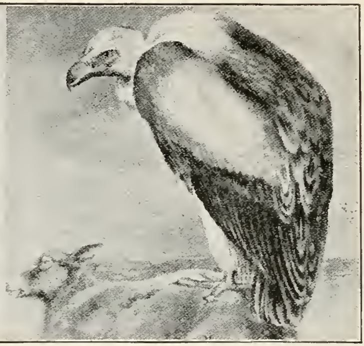
They have powerful feet and claws, but not such as would enable them to carry off heavy burdens to their nests. Their beaks are the great weapons of attack. With these the larger ones can tear off the skin of a horse or buffalo, and tear the flesh from the bones, so that nothing but the skeleton remains. A man in India who saw a host of these birds settle upon a dead horse said that in a marvelously short time there remained of the horse nothing but a clean-picked skeleton.

PHARAOH'S CHICKENS, AND THE VULTURE THAT EATS REPTILES

The king vulture's naked neck is colored with shades of orange, purple, and crimson, and it has extraordinary-colored fleshy wattles all round its nostrils and the root of its cruel-looking beak. All the vultures have this fact in their favor, that they are very good parents. Long ago the Egyptians so highly regarded the vulture, which in Egypt has the name of Pharaoh's chickens, that they frequently included it in their drawings and carvings as the emblem of the love of parents for their children. In some parts of the East the vulture is protected by law because of its value as a scavenger.

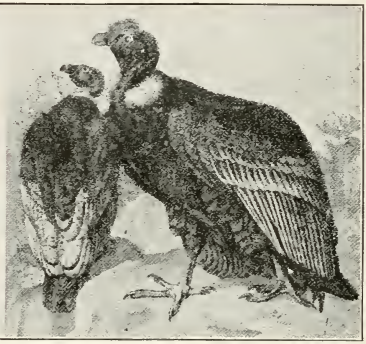


The strangest-looking vulture of the family is the king vulture, the flesh of whose extraordinary bare neck is brilliantly tinted with orange, purple, and crimson.

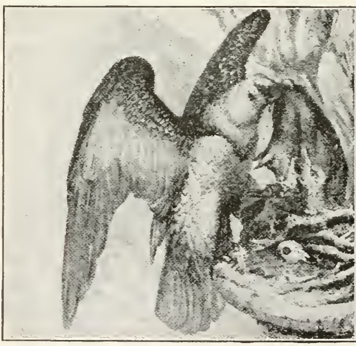


Griffin vultures are to be found in Europe and in the East. They build on high rocks, but sometimes steal the nests which eagles have made and left.

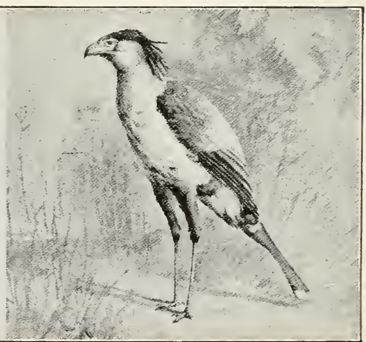
The Egyptian vulture was the chief scavenger of the land of Pharaoh. The Egyptians valued it highly, and carved its likeness on their monuments and tombs.



The condor is the largest of the vultures, and, indeed, of all birds of prey. It makes its great nest in high mountains, and flies as gracefully as a winged yacht.



The lammergeier is known as the bearded vulture. It descends from its mountain home to eat dead animals, and can carry smaller ones to its nest of young ones.



The secretary bird kills and eats snakes in South Africa. Its feathered head makes it look like a clerk, with a quill pen in his ear; hence its name.

Before passing from the vulture family we must say a good word for the secretary bird, which is really a vulture. It is a curious, long-legged, long-tailed bird, with a strong, hooked beak and strong legs armed with stout scales, and claws admirably adapted to the purpose which they have to serve. Its food consists of reptiles, and among these is included a great number of venomous serpents. The bird has no fear of them. Generally it dashes at the snake, and, with its wings spread out towards the front to keep the serpent from biting it, beats it, pecks it, and stamps on it until the snake is killed. Small snakes it swallows whole; larger ones it tears to pieces. This bird is found chiefly in South Africa, where it is so highly valued as the foe of snakes that a fine is imposed for killing it. It gets the name of secretary bird from the feathers which grow out from the back of its head, looking very much like quill pens behind the ear of a clerk.

Some of the smaller members of the family of bird hunters

Of course, there are smaller birds in this great family of hunters than those we have so far considered. The buzzards, kites, and falcons, though having much the same nature as their larger relatives, are built on a smaller scale. The buzzard measures from twenty to twenty-two inches in length, and it has the strong beak and sharp claws of its family. But it is not so active a bird as the rest. At times it flies gloriously high up, in great circles, with very few movements of the wings which the eye can detect. As a rule, however, it prefers to get its living easily, by watching and waiting, and pouncing at the right moment upon its victim, whether that victim be rat, mouse, reptile, or bird. Parts of its plumage are very downy, so that the bird can drop down upon its astonished victim without making a sound. Members of the tribe are to be found in Scotland, Ireland and America.

The evil work of the kite and the good work that it does

The kite robs rabbit warrens, and likes game birds; but the harm that it does in this way must be more than made up by the good it works in destroying rats and mice, and snakes and moles.

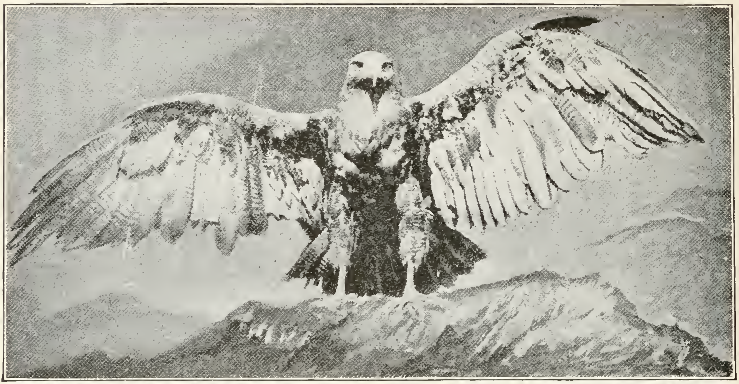
Next we come to the true falcons—handsome, noble-looking birds, of which the most famous are the gerfalcon, the peregrine, the lanner, the saker, the Barbary falcon, the Indian shaheen, the hobby, and the merlin—all long-winged, dark-eyed birds, which rise high in the air, then descend like thunderbolts upon their prey and bear it to the ground; then the strong, swift goshawk and sparrow-hawk, birds with shorter wings and yellow eyes, which catch their prey by flying after it in a straight line, and overcoming it by greater speed and strength.

How the falcon birds are taught to catch other birds for men

These birds play the same part in bird life that the cheetah plays in the animal world. Like the powerful cheetah, they are by nature wild and fierce, but they are trained to hunt for men.

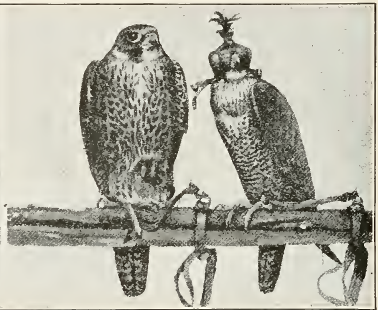
Soft leather straps are fastened to their legs so that they cannot fly away at will. A hood is put over the head, leaving the beak and nostrils free for breathing, but preventing the bird from seeing. When the hood is removed, the bird is shown a piece of meat, and has to hop from its perch on to the wrist of the man who holds the food. He has a glove on, so that the sharp talons of the bird will not hurt him.

When the bird gets used to this sort of treatment, it knows that by

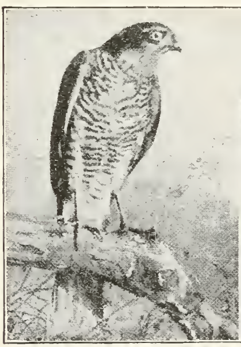


The buzzard is one of the handsomest of the falcon tribe. It is fierce but lazy, waiting in hiding, then pouncing on its prey without being heard Its feathers are downy, and make no sound as the bird flies.

The smallest falcon is the merlin, a fierce foe, but easy to make a friend of and to tame This is the bird which the lark flies so high to avoid

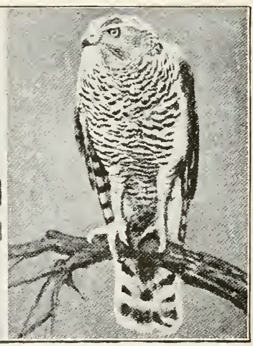


Men take out the peregrine falcon to hunt, with a hood put over its head. As the game appears, the hood is taken off, and the falcon sees its prey and flies after it.



The strong, fast-flying sparrow-hawk hunts blackbirds and thrushes, young partridges, rabbits and hares.

The kite has a forked tail, and looks, in flying, like a big swallow. Some species are well known as scavengers.



The goshawk catches its prey by its very swift flight, clutches it in its talons and drops to the ground with it.

jumping to the wrist it will be fed. Then the distance is increased. With a light line tied to its leg, it is made to fly twenty or thirty yards for its food. Then in time the line is removed from the leg, and the bird flies free. After awhile, instead of its usual food, it is made to fly to a bird or a small animal, and catches this and returns to the wrist of its master.

Like all other falcons, the peregrine is a magnificent hunter. It is supposed to be able to fly at the rate of one hundred and fifty miles an hour, yet it flies with such delicacy of direction that it can follow a smaller bird through mazes of branches and undergrowth, and take a bird off a bough without stopping or touching any part of the tree.

COMMON FARM AND ORCHARD BIRDS

The principal object of this section is to give concise information about the native birds that frequent farm, orchard and suburban districts. To aid the descriptions a number of illustrations in color are inserted to enable anyone—particularly boys and girls—to identify them; while the information itself will be found sufficiently full to disclose the good or harm certain birds do. Fifty of our commoner birds are discussed, including some that are destructive. They inhabit various parts of the country, and it is for the interest of the farmers of the respective localities to be familiar with them. The birds were drawn from nature by the well-known bird artist, Louis Agassiz Fuertes.

AMERICA is greatly favored in the number and character of its birds, which not only include some of the gems of the bird world, as the warblers and humming birds, but on the whole embrace few destructive species. Not only do many birds satisfy our senses through their beautiful plumage and their sweet voices, but they are marvelously adapted to their respective fields of activity. No other creatures are so well fitted to capture flying insects as swallows, swifts, and nighthawks. Among this class also are wrens, trim of body and agile of movement, that creep in and out of holes and crevices and explore rubbish heaps for hidden insects. The woodpecker, whose whole body exhibits wonderful adaptation of means to end, is provided with strong claws for holding firmly when at work, a chisel-like bill driven by powerful muscles to dig out insects, and a long extensible tongue to still further explore the hidden retreats of insects and drag forth the concealed larvæ, safe from other foes. The creepers, titmice, warblers, flycatchers, quails, doves, and other families have each their own special field of activity. However unlike they may be in appearance, structure, habits, all are similar in one respect—they possess a never flagging appetite for insects and weed seeds.

BIRDS OR INSECT DESTROYERS

Entomologists have estimated that insects yearly cause a loss of upwards of $700,000,000 to the agricultural interests of the United States. Were it not for our birds the loss would be very much greater, and indeed it is believed that without the aid of our feathered friends successful agriculture would be impossible.

Birds occupy a unique position among the enemies of insects, since their powers of flight enable them at short notice to gather at points where there are abnormal insect outbreaks. An unusual abundance of grasshoppers, for instance, in a given locality soon attracts the birds from a wide area, and as a rule their visits cease only when there are no grasshoppers left. So also a marked increase in the number of small rodents in a given neighborhood speedily attracts the attention of hawks and owls, which, by reason of their voracious appetites, soon produce a marked diminution of the swarming foe.

THE SPARROW FAMILY

One of the most useful groups of native birds is the sparrow family. While some of the tribe wear gay suits of many hues, most of the sparrows are clad in modest brown tints, and as they spend much of the time in grass and weeds are commonly overlooked. Unobtrusive as they are, they lay the farmer under a heavy debt of gratitude by their food habits, since their chosen fare consists largely of the seeds of weeds. Selecting a typical member of the group, the tree sparrow, for instance, one-fourth ounce of weed seed per day is a conservative estimate of the food of an adult. On this basis, in a large agricultural state like Iowa tree sparrows annually eat approximately 875 tons of weed seeds. Only the farmer, upon whose shoulders falls the heavy burden of freeing his land of noxious weeds, can realize what this vast consumption of weed seeds means in the saving and cost of labor. Some idea of the money value of this group of birds to the country may be gained from the statement that the total value of the farm products in the United States in 1910 reached the amazing sum of $8,926,000,000. If we estimate that the total consumption of weed seed by the combined members of the sparrow family resulted in a saving of only 1 per cent of the crops—not a violent assumption—the sum saved to farmers by these birds in 1910 was $89,260,000.

HAWKS AND OWLS

The current idea in relation to hawks and owls is erroneous. These birds are generally classed as thieves and robbers, whereas a large majority of them are the farmers' friends and spend the greater part of their long lives in pursuit of injurious insects and rodents. The hawks work by day, the owls chiefly by night, so that the useful activities of the two classes are continued practically throughout the twenty-four hours. As many as 100 grasshoppers have been found in the stomach of a Swainson's hawk, representing a single meal; and in the retreat of a pair of barn owls have been found more than 3000 skulls, 97 per cent of which were of mammals, the bulk consisting of field mice, house mice, and common rats. Nearly half a bushel of the remains of pocket gophers—animals which are very destructive in certain parts of the United States—was found near a nest of this species. A few hawks are injurious, and the bulk of the depredations on birds and chickens chargeable against hawks is committed by three species—the Cooper's hawk, the sharp-shinned hawk, and the goshawk.

From the foregoing it will at once appear that the practice of offering bounties indiscriminately for the heads of hawks and owls, as has been done by some states, is a serious mistake, the result being not only a waste of public funds but the destruction of valuable birds which can be replaced, if at all, only after the lapse of years.

The majority of owls are usually purely nocturnal—night birds. One or two species usually can see quite well in a bright light, but the majority cannot. Their eyes are so formed that they can collect light from what to us is darkness. They can see when the daylight is not quite gone; but in the direct light of the sun they are dazed.

The owl works and feeds when we are asleep. It has eyes differently placed from those of any other bird—close together in front, so that it must look straight ahead. To make up for this, it can turn its head with the

THE FIRST COUSINS OF THE OSTRICH

The cassowary lives in Australia and New Guinea. Its glossy feathers are like hair, and its head is crowned with a helmet. The male is smaller than the female.

The emu is a kind of cassowary. Its neck is feathered, not bare like the cassowary's. The female emu is bigger and fiercer than the male.

South America's ostrich is called the rhea. It has three toes; the African ostrich has only two. The rhea has no tail, but it has larger wings than the ostrich. Its feathers are used for making brushes. Those of the ostrich are more valuable, and the ostrich is carefully reared by ostrich farmers for the sake of its feathers. These big birds have strange appetites, and eat all sorts of things, broken bottles, etc., and seem none the worse.

greatest ease in any direction. The power of its eyes in the darkness is quite wonderful. Most of us, if we were quite close to a field mouse or rat moving stealthily over a field, would do well to see it against the earth, like which its coat is colored. But the owl sees it from afar through the darkness, pounces noiselessly down, and seizes it. It can catch the mouse and the mole and the rat; it can catch fish as they rise to the surface of the water.

How the courage of the owl goes in the daytime

There are about two hundred species of owls. Some are tiny owls; some are big eagle owls, twenty-eight inches in length, very fierce and strong, ready to attack a man who goes near, able to kill fawns and large game birds, and to do battle with the golden eagle. The courage of one of these owls goes in the daytime, and then little birds, led by a crow, may find it and mob it out into the open, and lead it a terrible dance. But when night comes, and the bird can see, none but a mighty eagle dare do battle with it.

The hawk owl is one of the few owls which work by day. It is big and strong and savage. There are owls with great ear-tufts of feathers, and owls with none at all; some are snowy white, others are mottled. Some live in burrows with the prairie marmots; some make burrows for themselves. Mostly they live in hollow trees, or in church belfries or other high towers. Among so many owls, of course, there are those which do harm, but the most of them do more good than evil.

The merciless crow that robs nests, and the jolly little jackdaw

The carrion crow has a nature like the vulture and the raven, but the bird is smaller, and when it attacks a big living animal it cannot do its work single handed, but advances in numbers. Its habit of eating putrid flesh is, of course, unpleasant, but it is of importance to the health of the place in which the crow finds its meals. Crows are merciless thieves. They rob other birds' nests, killing and eating the young ones, and even carrying off the unhatched eggs. To do this the crow thrusts his strong beak through one end of the egg, then carries the shell and its contents away as on a spear.

The jolly little jackdaw belongs to this family, and can be distinguished from the others by the patch of gray on the head and back of the neck. It builds in the steeples of churches and other high buildings. Everybody knows its relative, the magpie, from its handsome plumage of glossy black and white. We are all fond of this bird because of its bright ways; but other birds hate it, for it robs their nests as the crows do. When tamed, it is a wonderful talker.

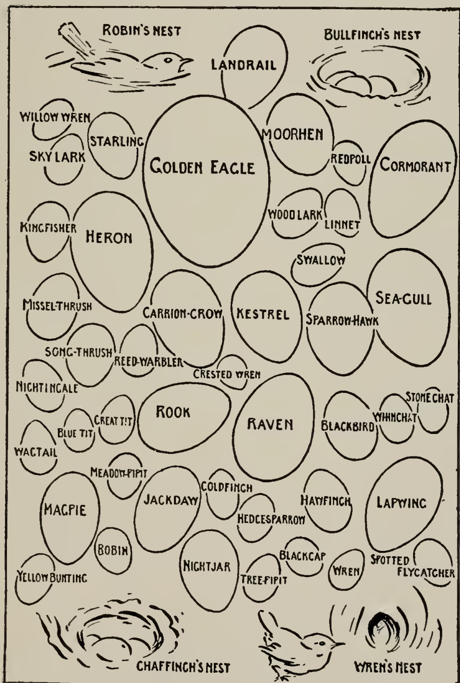
One of the most singular of the birds of prey is the shrike, or butcher bird. It catches small birds, mice, and so on, and fixes their bodies upon thorns; then it can easily skin and eat such as it wants, leaving the others for the time to come when it is once more hungry.

The birds' manner of living

As a rule birds do not live very long, but they live fast. They breathe rapidly and have a higher temperature and a more rapid circulation than other vertebrates. This is a fortunate circumstance, since to generate the requisite force to sustain their active bodies a large quantity of food is necessary, and as a matter of fact birds have to devote most of their waking hours to obtaining insects, seeds, berries, and other kinds of food. The activity of birds in the pursuit of insects is still further stimulated by the fact that the young of most species, even those which are by no means strictly insectivorous, require great quantities of animal food in the early weeks of existence, so that during the summer months—the flood time of insect life—birds are compelled to redouble their attacks on our insect foes to satisfy the wants of their clamorous young.

What birds eat

It is interesting to observe that hungry birds—and birds are hungry most of the time—are not content to fill their stomachs with insects or seeds, but after the stomach is stuffed until it will hold no more continue to eat till the crop or gullet also is crammed. It is often the case that when the stomach is opened and the contents piled up the pile is two or three times as large as the stomach when filled. Birds may truly be said to have healthy appetites. To show the astonishing capacity of birds' stomachs and to reveal the extent to which man is indebted to birds for the destruction of noxious insects, the following facts are given:



SIZE OF EGGS OF OUR BEST-KNOWN BIRDS

A tree swallow's stomach was found to contain 40 entire chinch bugs and fragments of many others, besides 10 other species of insects. A bank swallow in Texas devoured 68 cotton-boll weevils, one of the worst insect pests that ever invaded the United States; and 35 cliff swallows had taken an average of 18 boll weevils each. Two stomachs of pine siskins from Haywards, California, contained 1900 black olive scales and 300 plant lice. A killdeer's stomach taken in November in Texas contained over 300 mosquito larvæ. A flicker's stomach held 28 white grubs. A nighthawk's stomach collected in Kentucky contained 34 May beetles, the adult form of white grubs. Another nighthawk from New York had eaten 24 clover - leaf weevils and 375 ants. Still another nighthawk had eaten 340 grass-hoppers, 52 bugs, 3 beetles, 2 wasps, and a spider. A boat-tailed grackle from Texas had eaten at one meal about 100 cotton bollworms, besides a few other insects. A ring-necked pheasant's crop from Washington contained 8000 seeds of chickweed and a dandelion head. More than 72,000 seeds have been found in a single duck stomach taken in Louisiana in February.

Important in this connection is the planting near the house and even in out-of-the-way places on the farm of various berry-bearing shrubs, of which many are ornamental, which will supply food when snow is on the ground. Other species which are not berry eaters, like the woodpeckers, nuthatches, creepers, and chickadees, can be made winter residents of many farms, even in the North, by putting out at convenient places a supply of suet, of which they and many other birds are very fond, even in summer. Hedges and thickets about the farm are important to furnish nesting sites and shelter both from the elements and from the numerous enemies of birds.

Few are aware of the difficulty often experienced by birds in obtaining water for drinking and bathing, and a constant supply of water near the farmhouse will materially aid in attracting birds to the neighborhood and in keeping them there, at least till the time of migration. Shallow trays of wood or metal admirably serve the purpose, especially as birds delight to bathe in them.

One of the worst foes of our native birds is the house cat, and probably none of our native wild animals destroys as many birds on the farm, particularly fledglings, as cats. The household pet is by no means blameless in this respect, for the bird-hunting instinct is strong even in the well-fed tabby; but much of the loss of our feathered life is attributable to the half-starved stray, which in summer is as much at home in the groves and fields as the birds themselves. Forced to forage for their own livelihood, these animals, which are almost as wild as the ancestral wildcat, inflict an appalling loss on our feathered allies and even on the smaller game birds like the woodcock and bobwhite. If cats are to find place in the farmer's household, every effort should be made by carefully feeding and watching them to insure the safety of the birds. The cat without a home should be mercifully put out of the way.

DESCRIPTION OF SOME FAMILIAR AMERICAN BIRDS

BLUEBIRD (*Sialia sialis*)

Length,* about 6½ inches.

Range: breeds in the United States (west to Arizona, Colorado, Wyoming, and Montana), southern Canada, Mexico, and Guatemala; winters in the southern half of the eastern United States and south to Guatemala.

Habits and economic status: the bluebird is one of the most familiar tenants of the farm and dooryard. Everywhere it is hailed as the harbinger of spring, and wherever it chooses to reside it is sure of a warm welcome. This bird, like the robin, phoebe, house wren, and some swallows, is very domestic in its habits. Its favorite nesting sites are crannies in the farm buildings or boxes made for its use or natural cavities in old apple trees. For rent the bird pays amply by destroying insects, and it takes no toll from the farm crop. The bluebird's diet consists of 68 per cent of insects to 32 per cent of vegetable matter. The largest items of insect food are grasshoppers first and beetles next, while caterpillars stand third. All of these are harmful except a few of the beetles. The vegetable food consists chiefly of fruit pulp, only an insignificant portion of which is of cultivated varieties. Among wild fruits elderberries are the favorite. From the above it will be seen that the bluebird does no essential harm, but on the contrary eats many harmful and annoying insects. (See Farmers' Bul. 54, pp. 46–48, U. S. Dept. of Agriculture.)

*Measured from tip of bill to tip of tail

ROBIN (*Planesticus migratorius*)

Length, 10 inches.

Range: breeds in the United States (except the Gulf States), Canada, Alaska, and Mexico; winters in most of the United States and south to Guatemala.

Habits and economic status: in the North and some parts of the West the robin is among the most cherished of our native birds. Should it ever become rare where now common, its joyous summer song and familiar presence will be sadly missed in many a homestead The robin is an omnivorous feeder, and its food

BIRDS OF PREY AND GAME BIRDS

KING BIRD

SPARROW HAWK

COOPERS HAWK

BOB WHITE

RUFFED GROUSE

RED TAILED HAWK

PLOVER

SCREECH OWL

BARN OWL

BIRDS NOTED FOR SONG OR PLUMAGE

BLUE JAY

ROBIN

WOODPECKER

BOBOLINK

MOCKING BIRD

MEADOW LARK

GROSBEAK

THRUSH

BLUE BIRD

includes many orders of insects, with no very pronounced preference for any. It is very fond of earthworms, but its real economic status is determined by the vegetable food, which amounts to about 58 per cent of all. The principal item is fruit, which forms more than 51 per cent of the total food. The fact that in the examination of over 1200 stomachs the percentage of wild fruit was found to be five times that of the cultivated varieties suggests that berry-bearing shrubs, if planted near the orchard, will serve to protect more valuable fruits. In California in certain years it has been possible to save the olive crop from hungry robins only by the most strenuous exertions and considerable expense. The bird's general usefulness is such, however, that all reasonable means of protecting orchard fruit should be tried before killing the birds. (See Farmers' Bul. 54, pp. 44–46, U. S. Dept. of Agriculture.)

MOCKING BIRD (*Mimus polyglottos*)

Length, 10 inches. Most easily distinguished from the similarly colored loggerhead shrike (opp. p. 124) by the absence of a conspicuous black stripe through the eye.

Range: resident from southern Mexico north to California, Wyoming, Iowa, Ohio, and Maryland; casual farther north.

Habits and economic status: Because of its incomparable medleys and imitative powers, the mocking bird is the most renowned singer of the Western Hemisphere. Even in confinement it is a masterly performer, and formerly thousands were trapped and sold for cage birds, but this reprehensible practice has been largely stopped by protective laws. It is not surprising, therefore, that the mocking bird should receive protection principally because of its ability as a songster and its preference for the vicinity of dwellings. Its place in the affections of the South is similar to that occupied by the robin in the North. It is well that this is true, for the bird appears not to earn protection from a strictly economic standpoint. About half of its diet consists of fruit, and many cultivated varieties are attacked, such as oranges, grapes, figs, strawberries, blackberries, and raspberries. Somewhat less than a fourth of the food is animal matter, and grasshoppers are the largest single element. The bird is fond of cotton worms, and is known to feed also on the chinch bug, rice weevil, and bollworm. It is unfortunate that it does not feed on injurious insects to an extent sufficient to offset its depredations on fruit. (See Yearbook U. S. Dept. Agric. 1895, pp. 415–416, and Biol. Survey Bul. 30, pp. 52–56.)

ROSE-BREASTED GROSBEAK (*Zamelodia ludoviciana*)

Length, 8 inches.

Range: Breeds from Kansas, Ohio, Georgia (mountains), and New Jersey, north to southern Canada; winters from Mexico to South America.

Habits and economic status: this beautiful grosbeak is noted for its clear, melodious notes, which are poured forth in generous measure. The rosebreast sings even at midday during summer, when the intense heat has silenced almost every other songster. Its beautiful plumage and sweet song are not its sole claim on our favor, for few birds are more beneficial to agriculture. The rosebreast eats some green peas and does some damage to fruit. But this mischief is much more than balanced by the destruction of insect pests. The bird is so fond of the Colorado potato beetle that it has earned the name of "potato-bug bird," and no less than a tenth of the total food of the rosebreasts examined consists of potato beetles—evidence that the bird is one of the most important enemies of the pest. It vigorously attacks cucumber beetles and many of the scale insects. It proved an active enemy of the Rocky Mountain locust during that insect's ruinous invasions, and among the other pests it consumes are the spring and fall cankerworms, orchard and forest tent caterpillars, tussock, gipsy, and brown-tail moths, plum curculio, army worm, and chinch bug. In fact, not one of our birds has a better record. (See Biol. Survey Bul. 32, pp. 33–59.)

BOBOLINK (*Dolichonyx oryzivorus*)

Length, about 7 inches.

Range: breeds from Ohio northeast to Nova Scotia, north to Manitoba, and northwest to British Columbia; winters in South America.

Habits and economic status: when American writers awoke to the beauty and attractiveness of our native birds, among the first to be enshrined in song and story was the bobolink. Few species show such striking contrasts in color of the sexes, and few have songs more unique and whimsical. In its northern home the bird is loved for its beauty and its rich melody; in the South it earns deserved hatred by its destructiveness. Bobolinks reach the southeastern coast of the United States the last half of April just as rice is sprouting and at once begin to pull up and devour the sprouting kernels. Soon they move on to their northern breeding grounds, where they feed upon insects, weed seeds, and a little grain. When the young are well on the wing, they gather in flocks with the parent birds and gradually move southward, being then generally known as reed birds. They reach the rice fields of the Carolinas about August 20, when the rice is in the milk. Then until the birds depart for South America planters and birds fight for the crop, and in spite of constant watchfulness and innumerable devices for scaring the birds a loss of 10 per cent of the rice is the usual result. (See Biol. Survey Bul. 13, pp. 12–22.)

BREWER'S BLACKBIRD (*Euphagus cyanocephalus*)

Length, 10 inches. Its glossy purplish head distinguishes it from other blackbirds that do not show in flight a trough-shaped tail.

Range: Breeds in the West, east to Texas, Kansas, and Minnesota, and north to southern Canada; winters over most of the United States breeding range, south to Guatemala.

Habits and economic status: Very numerous in the West and in fall gathers in immense flocks, especially about barnyards and corrals. During the cherry season in California Brewer's blackbird is much in the orchards. In one case they were seen to eat freely of cherries, but when a neighboring fruit raiser began to plow his orchard almost every blackbird in the vicinity was upon the newly opened ground and close at the plowman's heels in its eagerness to get the insects exposed by the plow. Caterpillars and pupæ form the largest item of animal food (about 12 per cent). Many of these are cutworms, and cotton bollworms or corn earworms were found in 10 stomachs and codling-moth pupæ in 11. Beetles constitute over 11 per cent of the food. The vegetable food is practically contained in three items—grain, fruit, and weed seeds. Grain, mostly oats, amounts to 54 per cent; fruit, largely cherries, 4 per cent; and weed seeds, not quite 9 per cent. The grain is probably mostly wild, volunteer, or waste, so that the bird does most damage by eating fruit. (See Biol. Surv. Bul. 34, pp. 59–65.)

MEADOWLARKS (*Sturnella magna* and *Sturnella neglecta*)

Length, about $10\frac{3}{4}$ inches.

Range: Breed generally in the United States, southern Canada, and Mexico to Costa Rica; winter from the Ohio and Potomac Valleys and British Columbia southward.

Habits and economic status: Our two meadowlarks, though differing much in song, resemble each other closely in plumage and habits. Grassy plains and uplands covered with a thick growth of grass or weeds, with near-by water, furnish the conditions best suited to the meadowlark's taste. The song of the western bird is loud, clear, and melodious. That of its eastern relative is feebler and loses much by comparison. In many localities the meadowlark is classed and shot as a game bird. From the farmer's standpoint this is a mistake, since its value as an insect eater is far greater than as an object of pursuit by the sportsman. Both the boll weevil, the foe of the cotton grower, and the alfalfa weevil are among the beetles it habitually eats. Twenty-five per cent of the diet of this bird is beetles, half of which are predaceous ground beetles, accounted useful insects, and one-fifth are destructive weevils. Caterpillars form 11 per cent of the food and are eaten in every month in the year. Among these are many cutworms and the well-known army worm. Grasshoppers are favorite food and are eaten in every month and almost every day. The vegetable food (24 per cent of the whole) consists of grain and weed seeds. (See Yearbook U. S. Dept. Agr. 1895, pp. 420–426.)

RED-WINGED BLACKBIRD (*Agelaius phœniceus*)

Length, about $9\frac{1}{2}$ inches.

Range: Breeds in Mexico and North America south of the Barren Grounds; winters in southern half of United States and south to Costa Rica.

Habits and economic status: The prairies of the upper Mississippi Valley, with their numerous sloughs and ponds, furnish ideal nesting places for redwings, and consequently this region has become the great breeding ground for the species. These prairies pour forth the vast flocks that play havoc with grain-fields. East of the Appalachian Range, marshes on the shores of lakes, rivers, and estuaries are the only available breeding sites and, as these are comparatively few and small, the species is much less abundant than in the West. Redwings are eminently gregarious, living in flocks and breeding in communities. The food of the redwing consists of 27 per cent animal matter and 73 per cent vegetable. Insects constitute practically one-fourth of the food. Beetles (largely weevils, a most harmful group) amount to 10 per cent. Grasshoppers are eaten in every month and amount to about 5 per cent. Caterpillars (among them the injurious army worm) are eaten at all seasons and aggregate 6 per cent. Ants, wasps, bugs, flies, dragonflies, and spiders also are eaten. The vegetable food consists of seeds, including grain, of which oats is the favorite, and some small fruits. When in large flocks this bird is capable of doing great harm to grain. (See Biol. Survey Bul. 13, pp. 33–34.)

COMMON CROW (*Corvus brachyrhynchos*)

Length, 19 inches.

Range: Breeds throughout the United States and most of Canada; winters generally in the United States.

Habits and economic status: The general habits of the crow are universally known. Its ability to commit such misdeeds as pulling corn and stealing eggs and fruit and to get away unscathed is little short of marvelous. Much of the crow's success in life is due to cooperation, and the social instinct of the species has its highest expression in the winter roosts, which are sometimes frequented by hundreds of thousands of crows. From these roosts daily flights of many miles are made in search of food. Injury to sprouting corn is the most frequent complaint against this species, but by coating the seed grain with coal tar most of this damage may be prevented. Losses of poultry and eggs may be averted by proper housing and the judicious use of wire netting. The insect food of the crow includes wireworms, cutworms, white grubs and grasshoppers, and during outbreaks of these insects the crow renders good service. The bird is also an efficient scavenger. But chiefly because of its destruction of beneficial wild birds and their eggs the crow must be classed as a criminal, and a reduction in its numbers in localities where it is seriously destructive is justifiable. (See Farmers' Bul. 54, pp. 22–23.)

BLUE JAY (*Cyanocitta cristata*)

Length, $11\frac{1}{2}$ inches. The brilliant blue of the wings and tail combined with the black crescent of the upper breast and the crested head distinguish this species.

Range: Resident in the eastern United States and southern Canada, west to the Dakotas, Colorado, and Texas.

Habits and economic status: The blue jay is of a dual nature. Cautious and silent in the vicinity of its nest, away from it it is bold and noisy. Sly in the commission of mischief, it is ever ready to scream "thief" at the slightest disturbance. As usual in such cases, its remarks are applicable to none more than itself, a fact neighboring nest holders know to their sorrow, for during the breeding season the jay lays heavy toll upon the eggs and young of other birds, and in doing so deprives us of the services of species more beneficial than itself. Approximately three-fourths of the annual food of the blue jay is vegetable matter, the greater part of which is composed of mast, i. e., acorns, chestnuts, beechnuts, and the like. Corn is the principal cultivated crop upon which this bird feeds, but stomach analysis indicates that most of the corn taken is waste grain. Such noxious insects as wood-boring beetles, grasshoppers, eggs of various caterpillars and scale insects constitute about one-fifth of its food. (See Farmers' Bul. 54, pp. 18–19.)

NIGHTHAWK (*Chordeiles virginianus*)

Length, 10 inches. Not to be confused with the whippoorwill. The latter lives in woodland and is chiefly nocturnal. The nighthawk often flies by day, when the white bar across the wing and its nasal cry are distinguishing.

Range: Breeds throughout most of the United States and Canada; winters in South America.

Habits and economic status: The skilful evolutions of a company of nighthawks as the birds gracefully cleave the air in intersecting circles is a sight to be remembered. So expert are they on the wing that no insect is safe from them, even the swift dragonfly being captured with ease. Unfortunately their erratic flight tempts men to use them for targets, and this inexcusable practice is seriously diminishing their numbers, which is deplorable, since no birds are more useful. This species makes no nest, but lays its two spotted eggs on the bare ground, sometimes on the gravel roof of the city house. The nighthawk is a voracious feeder and is almost exclusively insectivorous. Some stomachs contained from 30 to 50 different kinds of insects, and more than 600 kinds have been identified from the stomachs thus far examined. From 500 to 1000 ants are often found in a stomach. Several species of mosquitoes, including *Anopheles*, the transmitter of malaria, are eaten. Other well-known pests destroyed by the nighthawk are the Colorado potato beetle, cucumber beetles, chestnut, rice, clover-leaf and cotton-boll weevils, billbugs, bark beetles, squash bugs, and moths of the cotton worm.

FLICKER (*Colaptes auratus*)

Length, 13 inches. The yellow under surface of the wing, yellow tail shafts, and white rump are characteristic.

Range: Breeds in the eastern United States west to the plains and in the forested parts of Canada and Alaska; winters in most of the eastern United States.

Habits and economic status: The flicker inhabits the open country rather than the forest and delights in park-like regions where trees are numerous and scattered. It nests in any large cavity in a tree and readily appropriates an artificial box. It is possible, therefore, to insure the presence of this useful bird about the farm and to increase its numbers. It is the most terrestrial of our woodpeckers and procures much of its food from the ground. The largest item of animal food is ants, of which the flicker eats more than any other common bird. Ants were found in 524 of the 684 stomachs examined and 98 stomachs contained no other food. One stomach contained over 5000 and two others held over 3000 each. While bugs are not largely eaten by the flicker, one stomach contained 17 chinch bugs. Wild fruits are next to ants in importance in the flicker's dietary. Of these sour gum and wild black cherry stand at the head. The food habits of this bird are such as to recommend it to complete protection. (See Biol. Survey Bul. 37, pp. 52–58.)

YELLOW-BELLIED SAPSUCKER (*Sphyrapicus varius*)

Length, about 8½ inches. Only woodpecker having top of head from base of bill red, combined with a black patch on breast.

Range: Breeds in northern half of the United States and southern half of Canada; winters in most of the States and south to Costa Rica.

Habits and economic status: The yellow-bellied sapsucker is rather silent and suspicious and generally manages to have a tree between himself and the observer. Hence the bird is much better known by its works than its appearance. The regular girdles of holes made by this bird are common on a great variety of trees; in all about 250 kinds are known to be attacked. Occasionally young trees are killed outright, but more loss is caused by stains and other blemishes in the wood which result from sapsucker punctures. These blemishes, which are known as bird pecks, are especially numerous in hickory, oak, cypress, and yellow poplar. Defects due to sapsucker work cause an annual loss to the lumber industry estimated at $1,250,000. The food of the yellow-bellied sapsucker is about half animal and half vegetable. Its fondness for ants counts slightly in its favor. It eats also wasps, beetles (including, however, very few wood-boring species), bugs, and spiders. The two principal components of the vegetable food are wild fruits of no importance and cambium (the layer just beneath the bark of trees). In securing the cambium the bird does the damage above described. The yellow-bellied sapsucker, unlike other woodpeckers, thus does comparatively little good and much harm. (See Biol. Survey Bul. 39.)

CHICKADEE (*Penthestes atricapillus*)

Length, about 5¼ inches.

Range: Resident in the United States (except the southern half east of the plains), Canada, and Alaska.

Habits and economic status: Because of its delightful notes, its confiding ways, and its fearlessness, the chickadee is one of our best known birds. It responds to encouragement, and by hanging within its reach a constant supply of suet the chickadee can be made a regular visitor to the garden and orchard. Though insignificant in size, titmice are far from being so from the economic standpoint, owing to their numbers and activity. While one locality is being scrutinized for food by a larger bird, 10 are being searched by the smaller species. The chickadee's food is made up of insects and vegetable matter in the proportion of 7 of the former to 3 of the latter. Moths and caterpillars are favorites and form about one-third of the whole. Beetles, ants, wasps, bugs, flies, grasshoppers, and spiders make up the rest. The vegetable food is composed of seeds, largely those of pines, with a few of the poison ivy and some weeds. There are few more useful birds than the chickadees. (See Farmers' Bul. 54, pp. 43–44.)

HOUSE WREN (*Troglodytes aëdon*)

Length, 4¾ inches. The only one of our wrens with wholly whitish underparts that lacks a light line over the eye.

Range. Breeds throughout the United States (except the South Atlantic and Gulf States) and southern Canada; winters in the southern United States and Mexico.

Habits and economic status: The rich, bubbling song of the familiar little house wren is one of the sweetest associations connected with country and suburban life. Its tiny body, long bill, sharp eyes, and strong feet peculiarly adapt it for creeping into all sorts of nooks and crannies where lurk the insects it feeds on. A cavity in a fence post, a hole in a tree, or a box will be welcomed alike by this busybody as a nesting site; but since the advent of the quarrelsome English sparrow such domiciles are at a premium and the wren's eggs and family are safe only in cavities having entrances too small to admit the sparrow. Hence it behooves the farmer's boy to provide boxes the entrances to which are about an inch in diameter, nailing these under gables of barns and outhouses or in orchard trees. In this way the numbers of this useful bird can be increased, greatly to the advantage of the farmer. Grasshoppers, beetles, caterpillars, bugs, and spiders are the principal elements of its food. Cutworms, weevils, ticks, and plant lice are among the injurious forms eaten. The nestlings of house wrens consume great quantities of insects. (See Yearbook U. S. Dept. Agric. 1895, pp. 416–418, and Biol. Survey Bul. 30, pp. 60–62.)

CATBIRD (*Dumetella carolinensis*)

Length, about 9 inches. The slaty gray plumage and black cap and tail are distinctive.

Range: Breeds throughout the United States west to New Mexico, Utah, Oregon, and Washington, and in southern Canada; winters from the Gulf States to Panama.

Habits and economic status: In many localities the catbird is one of the commonest birds. Tangled growths are its favorite nesting places and retreats, but berry patches and ornamental shrubbery are not disdained. Hence the bird is a familiar dooryard visitor. The bird has a fine song, unfortunately marred by occasional cat calls. With habits similar to those of the mocking bird and a song almost as varied, the catbird has never secured a similar place in popular favor. Half of its food consists of fruit, and the cultivated crops most often injured are cherries, strawberries, raspberries, and blackberries. Beetles, ants, crickets, and grasshoppers are the most important element of its animal food. The bird is known to attack a few pests, as cutworms, leaf beetles, clover-root curculio, and the periodical cicada, but the good it does in this way probably does not pay for the fruit it steals. The extent to which it should be protected may perhaps be left to the individual cultivator; that is, it should be made lawful to destroy catbirds that are doing manifest damage to crops. (See Yearbook U. S. Dept. Agric. 1895, pp. 406–411.)

BARN SWALLOW (*Hirundo erythrogasta*)

Length, about 7 inches. Distinguished among our swallows by deeply forked tail.

Range: Breeds throughout the United States (except the South Atlantic and Gulf States) and most of Canada; winters in South America.

Habits and economic status: This is one of the most familiar birds of the farm and one of the greatest insect destroyers. From daylight to dark on tireless wings it seeks its prey, and the insects destroyed are countless. Its favorite nesting site is a barn rafter, upon which it sticks its mud basket. Most modern barns are so tightly constructed that swallows can not gain entrance, and in New England and some other parts of the country barn swallows are much less numerous than formerly. Farmers can easily provide for the entrance and exit of the birds and so add materially to their numbers. It may be well to add that the parasites that sometimes infest the nests of swallows are not the ones the careful housewife dreads, and no fear need be felt of the infestation spreading to the houses. Insects taken on the wing constitute the almost exclusive diet of the barn swallow. More than one-third of the whole consists of flies, including unfortunately some useful parasitic species. Beetles stand next in order and consist of a few weevils and many of the small dung beetles of the May beetle family that swarm over the pastures in the late afternoon. Ants amount to more than one-fifth of the whole food, while wasps and bees are well represented.

PURPLE MARTIN (*Progne subis*)

Length, about 8 inches.

Range: Breeds throughout the United States and southern Canada, south to central Mexico; winters in South America.

Habits and economic status: This is the largest as it is one of the most beautiful of the swallow tribe. It formerly built its nests in cavities of trees, as it still does in wild districts, but learning that man was a friend it soon adopted domestic habits. Its presence about the farm can often be secured by erecting houses suitable for nesting sites and protecting them from usurpation by the English sparrow, and every effort should be made to increase the number of colonies of this very useful bird. The boxes should be at a reasonable height, say 15 feet from the ground, and made inaccessible to cats. A colony of these birds on a farm makes great inroads upon the insect population, as the birds not only themselves feed upon insects but rear their young upon the same diet. Fifty years ago in New England it was not uncommon to see colonies of 50 pairs of martins, but most of them have now vanished for no apparent reason except that the martin houses have decayed and have not been renewed. More than three-fourths of this bird's food consists of wasps, bugs, and beetles, their importance being in the order given. The beetles include several species of harmful weevils, as the clover-leaf weevils and the nut weevils. Besides these are many crane flies, moths, May flies, and dragonflies.

ENGLISH SPARROW (*Passer domesticus*)

Length, about $6\frac{1}{4}$ inches. Its incessant chattering, quarrelsome disposition, and abundance and familiarity about human habitations distinguish it from our native sparrows.

Range: Resident throughout the United States and southern Canada.

Habits and economic status: Almost universally condemned since its introduction into the United States, the English sparrow has not only held its own, but has ever increased in numbers and extended its range in spite of all opposition. Its habit of driving out or even killing more beneficial species and the defiling of buildings by its droppings and by its own unsightly structures, are serious objections to this sparrow. Moreover, in rural districts, it is destructive to grain, fruit, peas, beans, and other vegetables. On the other hand, the bird feeds to some extent on a large number of insect pests, and this fact points to the need of a new investigation of the present economic status of the species, especially as it promises to be of service in holding in check the newly introduced alfalfa weevil, which threatens the alfalfa industry in Utah and neighboring States. In cities most of the food of the English sparrow is waste material secured from the streets.

SPARROW HAWK (*Falco sparverius*)

Length, about 10 inches. This is one of the best known and handsomest, as well as the smallest, of North American hawks.

Range: Breeds throughout the United States, Canada, and northern Mexico; winters in the United States and south to Guatemala.

Habits and economic status: The sparrow hawk, which is a true falcon, lives in the more open country and builds its nest in hollow trees. It is abundant in many parts of the West, where telegraph poles afford it convenient perching and feeding places. Its food consists of insects, small mammals, birds, spiders, and reptiles. Grasshoppers, crickets, and terrestrial beetles and caterpillars make up considerably more than half its subsistence, while field mice, house mice, and shrews cover fully 25 per cent of its annual supply. The balance of the food includes birds, reptiles, and spiders. Contrary to the usual habits of the species, some individuals during the breeding season capture nestling birds for food for their young and create considerable havoc among the songsters of the neighborhood. In agricultural districts when new ground is broken by the plow, they sometimes become very tame, even alighting for an instant under the horses in their endeavor to seize a worm or insect. Out of 410 stomachs examined, 314 were found to contain insects; 129, small mammals; and 70, small birds. This little falcon renders good service in destroying noxious insects and rodents and should be encouraged and protected. (See Biol. Survey Bul. 3, pp. 115–127.)

RED-TAILED HAWK (*Buteo borealis*)

Length, about 2 feet. One of our largest hawks; adults with tail reddish brown.

Range: Breeds in the United States, Mexico, Costa Rica, Canada, and Alaska; winters generally in the United States and south to Guatemala.

Habits and economic status: The red-tailed hawk, or "hen-hawk," as it is commonly called, is one of the best known of all our birds of prey, and is a widely distributed species of great economic importance. Its habit of sitting on some prominent limb or pole in the open, or flying with measured wing beat over prairies and sparsely wooded areas on the lookout for its favorite prey, causes it to be noticed by the most indifferent observer. Although not as omnivorous as the red-shouldered hawk, it feeds on a variety of food, as small mammals, snakes, frogs, insects, birds, crawfish, centipedes, and even carrion. In regions where rattlesnakes abound it destroys considerable numbers of the reptiles. Although it feeds to a certain extent on poultry and birds, it is nevertheless entitled to general protection on account of the insistent warfare it wages against field mice and other small rodents and insects that are so destructive to young orchards, nursery stock, and farm produce. Out of 530 stomachs examined, 457, or 85 per cent, contained the remains of mammal pests such as field mice, pine mice, rabbits, several species of ground squirrels, pocket gophers, and cotton rats, and only 62 contained the remains of poultry or game birds. (See Biol. Survey Bul. 3, pp. 48–62.)

COOPER'S HAWK (*Accipiter cooperi*)

Length, about 15 inches. Medium sized, with long tail and short wings, and without the white patch on rump which is characteristic of the marsh hawk.

Range: Breeds throughout most of the United States and southern Canada; winters from the United States to Costa Rica.

Habits and economic status: The Cooper's hawk, or "blue darter," as it is familiarly known throughout the South, is preeminently a poultry- and bird-eating species, and its destructiveness in this direction is surpassed only by that of its larger congener, the goshawk, which occasionally in autumn and winter enters the United States from the North in great numbers. The almost universal prejudice against birds of prey is largely due to the activities of these two birds, assisted by a third, the sharp-shinned hawk, which in habits and appearance might well pass for a small Cooper's hawk. These birds usually approach under cover and drop upon unsuspecting victims, making great inroads upon poultry yards and game coverts favorably situated for this style of hunting. Out of 123 stomachs examined, 38 contained the remains of poultry and game birds, 66 the remains of other birds, and 12 the remains of mammals. Twenty-eight species of wild birds were identified in the abovementioned material. This destructive hawk, together with its two near relatives, should be destroyed by every possible means. (See Biol. Survey Bul. 3, pp. 38–43.)

MOURNING DOVE (*Zenaidura macroura*)

Length, 12 inches. The dark spot on the side of the neck distinguishes this bird from all other native doves and pigeons except the white-winged dove. The latter has the upper third of wing white.

Range: Breeds throughout the United States and in Mexico, Guatemala, and southern Canada; winters from the central United States to Panama.

Habits and economic status: The food of the mourning dove is practically all vegetable matter (over 99 per cent), principally seeds of plants, including grain. Wheat, oats, rye, corn, barley, and buckwheat were found in 150 out of 237 stomachs, and constituted 32 per cent of the food. Three-fourths of this was waste grain picked up after harvest. The principal and almost constant diet is weed seeds, which are eaten throughout the year and constitute 64 per cent of the entire food. In one stomach were found 7500 seeds of yellow wood sorrel, in another 6400 seeds of barn grass or foxtail, and in a third 2600 seeds of slender paspalum, 4820 of orange hawkweed, 950 of hoary vervain, 120 of Carolina cranesbill, 50 of yellow wood sorrel, 620 of panic grass, and 40 of various other weeds. None of these are useful, and most of them are troublesome weeds. The dove does not eat insects or other animal food. It should be protected in every possible way. (See Farmers' Bul. 54, pp. 6–7.)

KILLDEER (*Oxyechus vociferus*)

Length, 10 inches. Distinguished by its piercing and oft-repeated cry—*kildee*.

Range: Breeds throughout the United States and most of Canada; winters from central United States to South America.

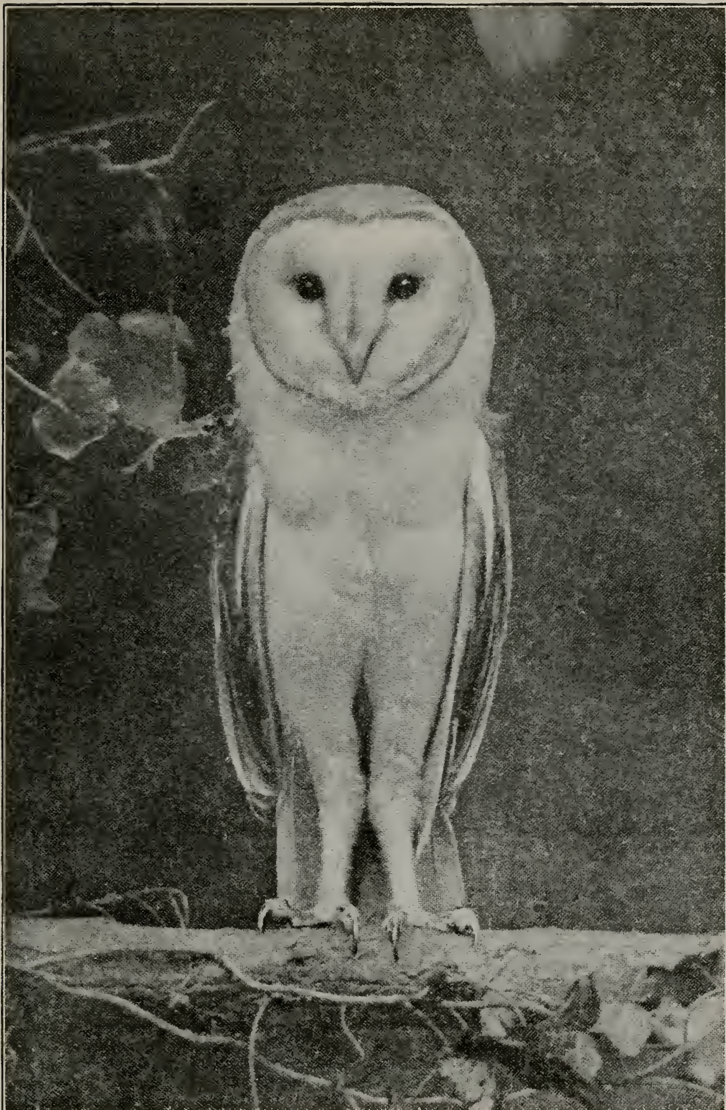
Habits and economic status: The killdeer is one of the best known of the shorebird family. It often visits the farmyard and commonly nests in pastures or cornfields. It is rather suspicious, however, and on being approached takes flight with loud cries. It is noisy and restless, but fortunately most of its activities result in benefit to man. The food is of the same general nature as that of the upland plover, but is more varied. The killdeer feeds upon beetles, grasshoppers, caterpillars, ants, bugs, caddis flies, dragonflies, centipedes, spiders, ticks, oyster worms, earthworms, snails, crabs, and other crustacea. Among the beetles consumed are such pests as the alfalfa weevil, cotton-boll weevil, clover-root weevil, clover-leaf weevil, pine weevil, billbugs, white grubs, wireworms, and leaf beetles. The bird also devours cotton worms, cotton cutworms, horse-flies, mosquitoes, cattle ticks, and crawfish. One stomach contained hundreds of larvæ of the salt-marsh mosquito, one of the most troublesome species. The killdeer preys extensively upon insects that are annoying to man and injurious to his stock and crops, and this should be enough to remove it from the list of game birds and insure its protection. (See Farmers' Bul. 497, pp. 16–18.)

UPLAND PLOVER (*Bartramia longicauda*)

Length, 12 inches. The only plainly colored shorebird which occurs east of the plains and inhabits exclusively dry fields and hillsides.

Range: Breeds from Oregon, Utah, Oklahoma, Indiana, and Virginia, north to Alaska; winters in South America.

Habits and economic status: This, the most terrestrial of our waders, is shy and wary, but it has the one weakness of not fearing men on horseback or in a vehicle. One of these methods of approach, therefore, is nearly always used by the sportsman, and, since the bird is highly prized as a table delicacy, it has been hunted to the verge of extermination. As the upland plover is strictly beneficial, it should no longer be classed as a game bird and allowed to be shot. Ninety-seven per cent of the food of this species consists of animal forms, chiefly of injurious and neutral species. The vegetable food is mainly weed seeds. Almost half of the total subsistence is made up of grasshoppers, crickets, and weevils. Among the weevils eaten are the cotton-boll weevil, greater and lesser clover-leaf weevils, cowpea weevils, and billbugs. This bird devours also leaf beetles, wireworms, white grubs, army worms, cotton



THE LONELY TENANT OF A LANE BY NIGHT—THE BARN-OWL OF THE COUNTRYSIDE worms, cotton cutworms, sawfly larvæ, horse-flies, and cattle ticks. In brief, it injures no crop, but consumes a host of the worst enemies of agriculture. (See Farmers' Bul. 497, pp. 14–16.)

KINGBIRD (*Tyrannus tyrannus*)

Length, about 8½ inches. The white lower surface and white-tipped tail distinguish this flycatcher.

Range: breeds throughout the United States (except the southwestern part) and southern Canada; winters from Mexico to South America.

Habits and economic status: the kingbird is a pronounced enemy of hawks and crows, which it vigorously attacks at every opportunity, thereby affording efficient protection to near-by poultry yards and young chickens at large. It loves the open country and is especially fond of orchards and trees about farm buildings. No less than 85 per cent of its food consists of insects, mostly of a harmful nature. It eats the common rose chafer or rose bug, and more remarkable still it devours blister beetles freely. The bird has been accused of eating honeybees to an injurious extent, but there is little ground for the accusation, as appears from the fact that examination of 634 stomachs showed only 61 bees in 22 stomachs. Of these 51 were useless drones. On the other hand, it devours robber flies, which catch and destroy honeybees. Grasshoppers and crickets, with a few bugs and some cutworms, and a few other insects, make up the rest of the animal food. The vegetable food consists of fruit and a few weeds. The kingbird deserves full protection. (See Biol. Survey Bul. 44, pp. 11–19.)

SCREECH OWL (*Otus asio*)

Length, about 8 inches. Our smallest owl with ear tufts. There are two distinct phases of plumage, one grayish and the other bright rufous.

Range: resident throughout the United States, southern Canada, and northern Mexico.

Habits and economic status: the little screech owl inhabits orchards, groves, and thickets, and hunts for its prey in such places as well as along hedge rows and in the open. During warm spells in winter it forages quite extensively and stores up in some hollow tree quantities of food for use during inclement weather. Such larders often contain enough mice or other prey to last it over a week or more. With the exception of the burrowing owl it is probably the most insectivorous of the noctural birds of prey. It feeds on small mammals, birds, reptiles, batrachians, fish, spiders, crawfish, scorpions, and earthworms. Grasshoppers, crickets, ground-dwelling beetles, and cater-pillars are its favorites among insects, as are field mice among mammals and sparrows among birds. Out of 324 stomachs examined, 169 were found to contain insects; 142, small mammals, 56, birds; and 15, crawfish. The screech owl should be encouraged to stay near barns and outhouses, as it will keep in check house mice and wood mice, which frequent such places. (See Biol. Survey Bul. 3, pp. 163–173.)

BARN OWL (*Aluco pratincola*)

Length, about 17 inches. Facial disk not circular as in our other owls; plumage above, pale yellow; beneath, varying from silky white to pale bright tawny.

Range: resident in Mexico, in the southern United States, and north to New York, Ohio, Nebraska, and California.

Habits and economic status: the barn owl, often called monkey-faced owl, is one of the most beneficial of the birds of prey, since it feeds almost exclusively on small mammals that injure farm produce, nursery, and orchard stock. It hunts principally in the open and consequently secures such mammals as pocket gophers, field mice, common rats, house mice, harvest mice, kangaroo rats, and cotton rats. It occasionally captures a few birds and insects. At least a half bushel of the remains of pocket gophers have been found in the nesting cavity of a pair of these birds. Remembering that a gopher has been known in a short time to girdle seven apricot trees worth $100 it is hard to overestimate the value of the service of a pair of barn owls. One thousand two hundred and forty-seven pellets of the barn owl collected from the Smithsonian towers contained 3,100 skulls, of which 3,004, or 97 per cent, were of mammals; 92 or 3 per cent, of birds; and 4 were of frogs. The bulk consisted of 1,987 field mice, 656 house mice, and 210 common rats. The birds eaten were mainly sparrows and blackbirds. This valuable owl should be rigidly protected throughout its entire range. (See Biol. Survey Bul. 3, pp. 132–139.)

RUFFED GROUSE (*Bonasa umbellus*)

Length, 17 inches. The broad black band near tip of tail distinguishes this from other grouse.

Range: resident in the northern two-thirds of the United States and in the forested parts of Canada.

Habits and economic status: the ruffed grouse, the famed drummer and finest game bird of the northern woods, is usually wild and wary and under reasonable protection well withstands the attacks of hunters. Moreover, when reduced in numbers, it responds to protection in a gratifying manner and has proved to be well adapted to propagation under artificial conditions. Wild fruits, mast, and browse make up the bulk of the vegetable food of this species. It is very fond of hazelnuts, beechnuts, chestnuts and acorns, and it eats practically all kinds of wild berries and other fruits. Nearly 60 kinds of fruits have been identified from the stomach contents examined. Various weed seeds also are consumed. Slightly more than 10 per cent of the food consists of insects, about half being beetles. The most important pests devoured are the potato beetle, clover-root weevil, the pale-striped flea beetle, grapevine leaf-beetle, May beetles, grasshoppers, cotton worms, army worms, cutworms, the red-humped apple worm, and sawfly larvæ. While the economic record of the ruffed grouse is fairly commendable, it does not call for more stringent protection than is necessary to maintain the species in reasonable numbers. (See Biol. Survey Bul. 24, pp. 25–38.)

BOBWHITE (*Colinus virginianus*)

Length, 10 inches. Known everywhere by the clear whistle that suggests its name.

Range: resident in the United States east of the plains; introduced in many places in the West.

Habits and economic status: the bobwhite is loved by every dweller in the country and is better known to more hunters in the United States than any other game bird. It is no less appreciated on the table than in the field, and in many states has unquestionably been hunted too closely. Fortunately it seems to be practicable to propagate the bird in captivity, and much is to be hoped for in this direction. Half the food of this quail consists of weed seeds, almost a fourth of grain, and about a tenth of wild fruits. Although thus eating grain, the bird gets most of it from stubble. Fifteen per cent of the bobwhite's food is composed of insects, including several of the most serious pests of agriculture. It feeds freely upon Colorado potato beetles and chinch bugs; it devours also cucumber beetles, wireworms, billbugs, clover-leaf weevils, cotton-boll weevils, army worms, bollworms, cutworms, and Rocky Mountain locusts. Take it all in all, bobwhite is very useful to the farmer, and while it may not be necessary to remove it from the list of game birds every farmer should see that his own farm is not depleted by eager sportsmen. (See Biol. Survey Bul. 21, pp. 9–46.)

DOWNY WOODPECKER (*Dryobates pubescens*)

Length, 6 inches. Our smallest woodpecker; spotted with black and white. Dark bars on the outer tail feathers distinguish it from the similarly colored but larger hairy woodpecker.

Range: Resident in the United States and the forested parts of Canada and Alaska.

Habits and economic status: This woodpecker is commonly distributed, living in woodland tracts, orchards and gardens. The bird has several characteristic notes, and, like the hairy woodpecker, is fond of beating on a dry resonant tree branch a tattoo which to appreciative ears has the quality of woodland music. In a hole excavated in a dead branch the downy woodpecker lays four to six eggs. This and the hairy woodpecker are among our most valuable allies, their food consisting of some o: the worst foes of orchard and woodland, which the woodpeckers are especially equipped to dig out of dead and living wood. In the examination of 723 stomachs of this bird, animal food, mostly insects, was found to constitute 76 per cent of the diet and vegetable matter 24 per cent. The animal food consists largely of beetles that bore into timber or burrow under the bark. Caterpillars amount to 16 per cent of the food and include many especially harmful species. Grasshopper eggs are freely eaten. The vegetable food of the downy woodpecker consists of small fruit and seeds, mostly of wild species. It distributes seeds of poison ivy, or poison oak, which is about the only fault of this very useful bird. (See Biol. Survey Bul. 37, pp. 17–22.)

WHAT HAPPENS IN A HIVE OF BEES

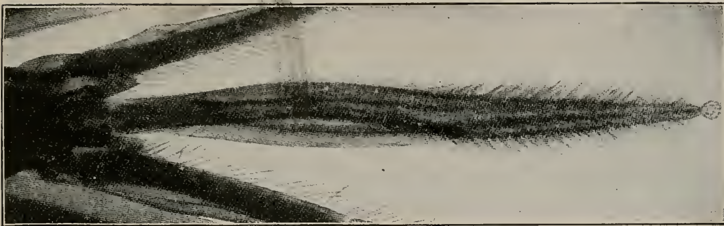
IF YOU have ever seen a swarm of bees issue from a hive, fill the summer morning with a cloud of flashing wings and glad riot of music, and then come to rest at last, all the thousands of reckless truants gathered in one dense, silent mass, gently swaying from the branch of a tree, you have seen one of the most mysterious sights in all the round of Nature.

The wonder of it lies not so much in the spectacle itself, although that is startling, but in the fact that the honey-bees, of all creatures on earth, should behave in this surprising way. If the honey-bees were in the habit of congregating in this way on fine summer mornings, returning to their hive after a few hours' enjoyment of the air and sunshine, it would be interesting, yet little more; but that is not what happens. That is not the habit of the bees. This great swarm of theirs is the first they have known, and of the thousands that have issued so jubilantly from the hive, which has been home to them from their first moment of life, not one will ever return. The swarm, from now onward, will become a separate colony of bees; and even if the new home should be within a few feet of the old home, and hard times should come upon it, every bee in the new home will starve, and die at her post, rather than go back to the place where prosperity and plenty await her after only an instant's flight.

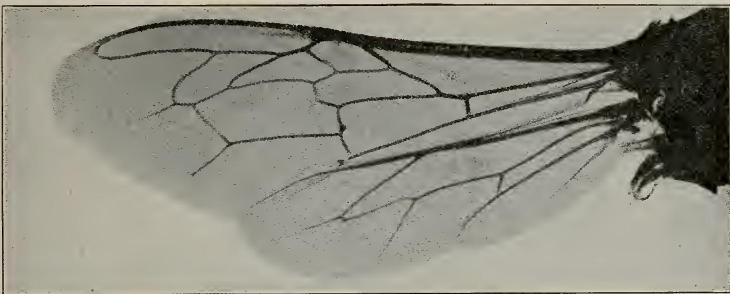
Moreover, we are faced with this mysterious thing. Today, before the swarm has issued, the twenty or thirty thousand worker bees, destined to go forth in a few hours, would instantly defend the mother hive against an assailant with their last energy and the last drop of venom in their stings. But tomorrow when the new colony has come into existence, not a single one of those bees would stir a wing to save the old home that was all-in-all to them but yesterday, no matter what danger might threaten it. As far as they are concerned, the old home has now utterly ceased to exist.

Swarm of Bees Hanging From a Beam

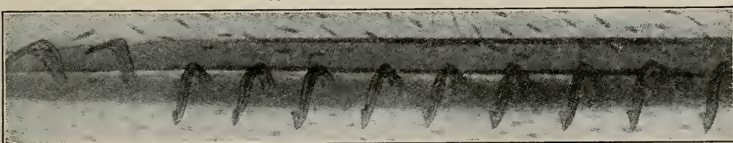
We see the hive at one moment going about its business in a quiet and orderly fashion, and the next suddenly throwing a dark and living stream upon the air. We see the winged multitude flinging itself broadcast overhead in what appears to be a mad confusion. But then we see a common purpose gradually reveal itself amid this chaos. The madly pirouetting, vociferating crew, after sailing about bodily hither and thither against the blue sky, at length seems to be concentrating at one spot. At the tip of a branch a little knot of bees has formed itself, no bigger than a single leaf; but even as we gaze this black spot doubles its volume. A moment more, and it has doubled again, and it grows and grows, as we watch, at amazing speed. We note now that, from all quarters, the flying bees are streaming towards this common center. In an incredibly brief interval, the air is empty of winged life. Every bee has attached herself to the cluster, and the branch is bowed down with the



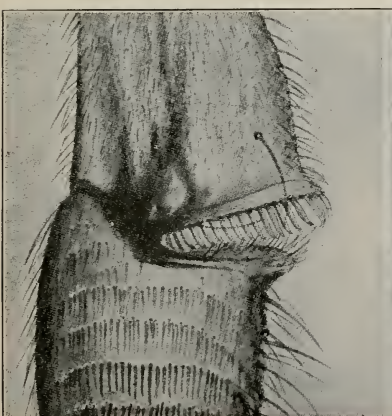
The tongue and mouth of a bee



The upper and lower wings of the honey bee



The hooks that hold the upper and lower wings of a bee together when in flight

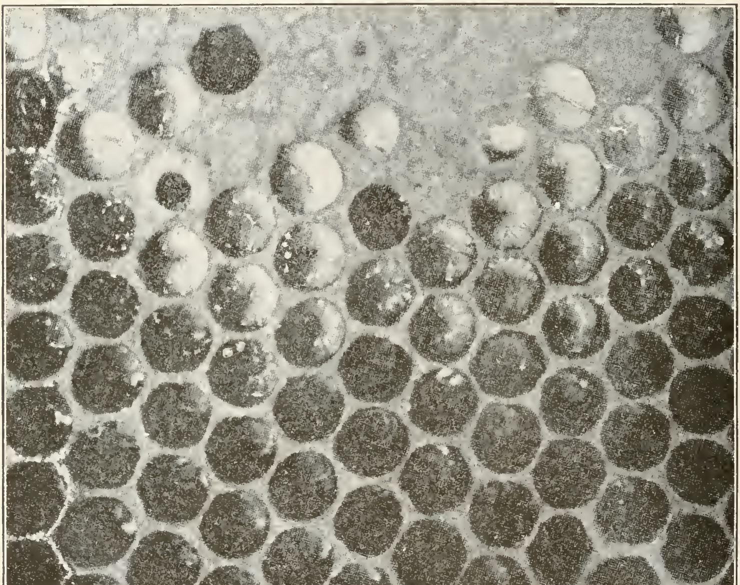


The empty pollen pocket of the bee, in the joint of its leg

The pollen pocket of the bee laden after a visit to the garden

THE GROWTH OF THE HONEY-BEE IN THE TINY CELL

THE DEVELOPMENT OF THE BEE FROM THE EGG LAID IN THE CELLS



THE EGGS LAID BY THE QUEEN IN THE CELLS, SHOWN IN VARIOUS STAGES OF DEVELOPMENT

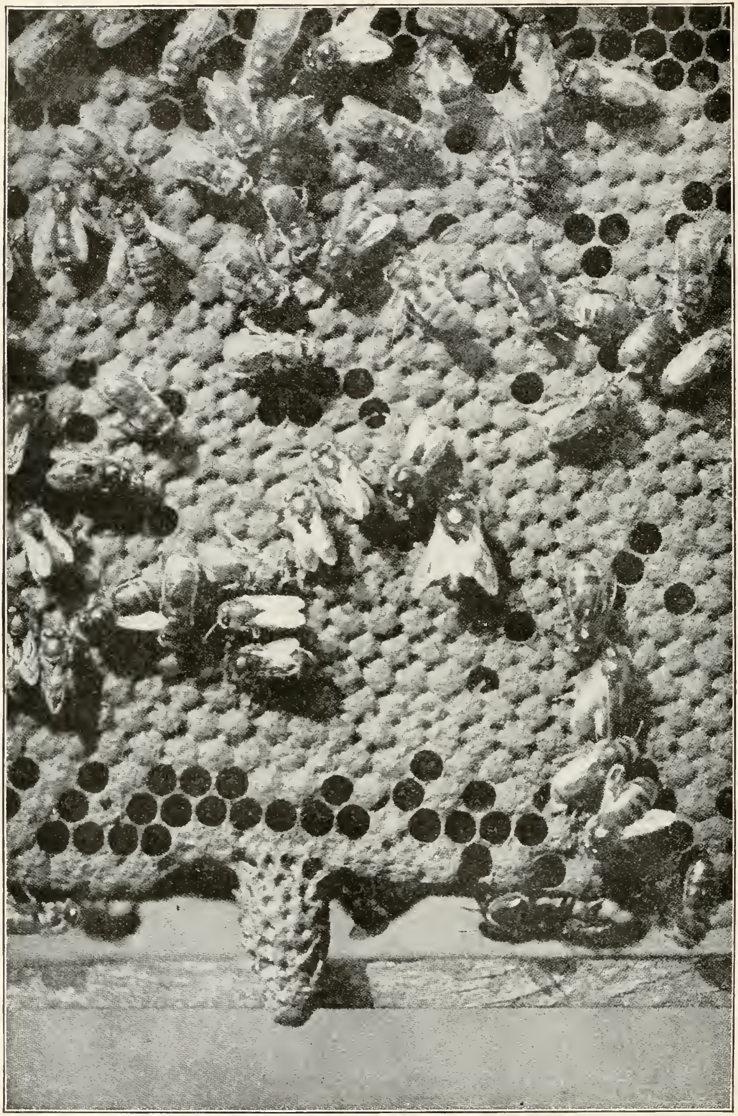
THE WISE LITTLE CREATURES THAT EMERGE FROM THE EGGS SEEN ABOVE—THE QUEEN BEE IS IN THE MIDDLE, WITH A DRONE ON HER LEFT AND A WORKER ON THE RIGHT.

weight of it, almost to the ground. There it hangs, a dark brown, glistening, cigar-shaped mass, idly swaying to and fro in the sun.

And now let us see what manner of creature it is that has done this thing. For 364 days out of 365 in the year a hive of bees presents an almost perfect example of law and order, prudence, and untiring industry. Every member of the colony—and in the height of summer a colony may consist of fifty or sixty thousand individuals—has its allotted work to do, and does it in a very fever of conscientiousness, resting neither day nor night. The queen, the one mother bee in the hive, passes incessantly over the combs, depositing eggs in the little cells to the number of several thousands in a single day. The worker bees hurry in and out of the hive, bringing in nectar from the flowers, to be brewed into thick, golden honey; or bringing pollen to be made into food for the young bees when they are only tiny white grubs with staring black eyes, lying inert in the cells; or bringing water, which is indispensable at nearly all stages of the life of a bee. Even the drones, of which there are only a few hundreds in each hive, have their appointed tasks. The drone is by no means the idle, dissolute fellow he is made out to be in the old-fashioned Nature books. He does not work simply because he has not been provided with any tools of labor—his tongue is too short to reach the nectar at the base of the flower-cups, he has no baskets on his thighs in which to transport the pollen, he cannot make wax or build up honeycomb. But he, as well as the workers, has many important offices vital to the well-being of the hive.

So the hive goes on, day after day, month after month, until the colony reaches its high tide of prosperity in the late spring. The store-houses are full to overflowing; the hive is crowded to the very door with a great population of bees; thousands more are being born every day. And then this strange thing happens. The creatures who have been at such infinite pains to bring about all this fullness and prosperity, whose industry and ingenuity have resulted in such an amazing structure, such an abounding accumulation of wealth, appear suddenly to go back on all their long-cherished principles. They throw work to the winds, rush madly to sport and play, abandon forever all their possessions, and utterly beggar themselves—all, as far as we can see, for the wild frolic of an hour. And tomorrow we shall see them sober and industrious again, as forgetful, apparently, of their wild escapade as they are of the very existence of the home of plenty they have forsaken for all time, beginning life afresh, with a feverish accession of energy, as they attach the first atom of wax to their empty house, and hurry forth to gather the first drop of nectar, or first pollen-loads, to feed the children yet unborn.

The issue of a swarm is inevitably connected with another thing perhaps more curious still. Though a great army of bees has come surging out of the hive, many have remained behind. If we look into the hive immediately after the departure of the swarm, we find there still a great gathering. The ordinary daily affairs of the colony seem to go forward in the old way, in spite of the upheaval. The combs are covered with bees engaged in the usual occupations—storing the nectar, feeding the young grubs, sealing over the ripe honey-cells, and closing up the cells in which the larvæ have reached full growth. And the question at once rises in the mind—why did all those bees rush from the home, never to



The queen bee deposits an egg in each cell in this comb. The royal cells are all constructed like the large cell at the bottom.

return, while all these others remained at their tasks, apparently unconcerned? By what means were some chosen and the others left?

As far as is known, no man has ever been able to answer that question. It is certain that the bees to go are chiefly mature workers accustomed to fly abroad, and that they take with them the queen of the old colony. It is certain, also, that the majority of the bees that remain are young workers and drones, whose experience of out of doors has been mostly confined to short airing flights in the midday sunshine round the hive. But that is all we know—that the stock does divide itself in this way, and the phenomenon must depend on urgent, definite laws—it must fulfil some imperious need, for it is obviously brought about by forces that are instant and irresistible.

Yet, though the life of the honeybee must ever rouse a spirit of wonder, it is not always fraught with mystery. There are aspects of it that the wisest of us may never come to understand; but, considered as an intelligent system, it is far from being mysterious; intricate and ingenious as it appears to us, its meaning and purpose stand out clear as day.

Bees are ordained to live together in a dense community, all the energy and ability of thousands of individuals united for the common good. What, then, do we see in a hive? The first things we see are the unique systems of rearing the young, and methods of making and storing honey, which is merely food laid by for the coming winter. For both of these purposes a continuous high temperature is needed, and the hive is therefore a closed receptacle, so that heat may be retained. But this warmth must first be generated and then economized, and both objects are attained by restricting the enclosed space to the least dimensions needed for the combs and the living heat-producers, the inhabitants of the hive. Limitation of space being thus necessary, it follows that the cells, which are needed for rearing the brood and storing the honey, must be made of the thinnest material, and of such a shape that they will pack together in the least possible compass. How does the honeybee solve this problem?

First, the bee proceeds to create within her own body a material which is lighter, tougher, and more elastic than anything that can be obtained out of doors. Then she ascertains the size of cell necessary for a full-sized grub, and proceeds to fashion a series of these cells. She makes each cell six-sided in form, because cells of this shape will fit together side by side over a given surface without leaving any waste spaces between. Moreover, a larger number of six-sided cells will go into a given area than cells of any other shape.

And now the bee perfects her scheme for greatest efficiency and economy by two crowning strokes. Every cell must be closed in at one end. Instead of grouping her cells in horizontal planes mouth upwards, as do the wasps, she places them on their sides, building a vertical wall with them, and sets two of these walls back to back, so that one partition will suffice to close two cells. But a still more ingenious economy in material is now brought about. Instead of making the cell-bottom flat, the bee constructs it of three diamond-shaped plates which fit together, forming a blunt pyramid. The result is that the cells, while retaining their necessary length in their centers, fit together where they meet back to back, like the teeth of a rat-trap, overlapping each other, and thus saving considerable in both space and material. The comb of the honeybee exists today, in this age of mechanical wonders, as one of the most ingenious mechanical contrivances in the world.

But perhaps the most wonderful thing about a beehive consists not in any custom or achievement of its inhabitants, but in the bodily structure of the worker bee herself. The fact that she accomplishes so many great works and overcomes so many difficulties seems less of a miracle when we watch her under the microscope, see how wonderfully she is made, and with what a sheaf of ingenious implements she is provided. She is first of all to be a honeymaker, and is therefore equipped with a tongue which can be used either as a sort of sponge to take up minute quantities of nectar, or as a tube which can be thrust into the finest apertures, and by which the most carefully hidden stores can be sucked up. For the conveyance of these sweets to the hives, she has within her body an elastic reservoir whose contents can be discharged through the mouth at will.

On the worker bee devolves the duty of supplying the pollen, an indispensable ingredient of the food given to the young larvæ, to the stay-at-home queen, to the drones, and sometimes to the workers themselves. For the purpose of collecting this pollen, nearly the whole of the body of the bee is covered with curiously branched hairs, like herring-bones, to which the grains of pollen adhere as the bee climbs into the flower. From these hairs the pollen is removed every moment or two by a process of grooming, which the bee carries out by means of a pair of beautifully constructed curry-combs carried on the hind legs. From these combs the pollen grains are again removed and kneaded together, after which the mass is packed into baskets formed by the stiff bristles on the thigh. The pollen thus accumulated often makes a lump of immense size compared with that of its bearer, and the bees may be seen fairly staggering into the hive under the weight of their golden loads.

The method of constructing the cells is even more remarkable than the method of provisioning them. These have to be made of excessive thinness in order that as little space as possible may be taken up, but they must be capable of bearing immense strains, and of resisting the high temperature of the hive. There is no natural substance affording all the qualities needed by the bee for her building work, so she must create it for herself. This she does by means of her wax-pockets—six tiny crucibles lying under the hard plates of the lower part of her body. In these pockets are generated tiny oval scales looking like flakes of clear glass, and this is the raw material of the comb. The bee has two pairs of pincers, one on each of her hind legs, and with these she draws out the brittle scales from her wax-pockets, and proceeds to chew them up, mingling with the substance a strong acid secreted by certain glands in the jaws. Then, and only then, does the material we know as beeswax come into existence, and the worker immediately sets about the task of molding it into comb.

But all this marvelous work of comb-building, with its exquisite regularity of form and accuracy of dimension, is carried on in what seems to us total darkness. How is it possible for the bees to construct it so perfectly, working in crowded companies together, the whole comb growing outward and downward in all directions at one and the same time? Here, again, we are faced with a question which the ingenuity of man has failed to answer. A partial explanation may be found in the fact that the bee is provided with eyes which actually make light of what we regard as complete darkness, but this will not solve the difficulty. Vision alone, however perfect, could never guide the bee in all the tasks she performs within the hive. Perhaps she has not only our own five senses, but other senses of which we can form little conception. An examination of her antennæ—the curious flail-like organs protruding from the middle of her forehead, which she incessantly uses in all her affairs—discloses evidence of this. On these antennæ we find no less than six distinct kinds of implements, all obviously organs of sense, and all perhaps conveying different impressions. We cannot be far wrong, therefore, in imagining that the bee has faculties, inconceivable in ourselves, which are necessary in her own special place in the scheme of life.

It would be easy to go on thus multiplying instances of the bee's amazing equipment for the work she does in the world. Many books have been filled with stories of this little friend of ours, one of the most interesting creatures in the universe. But we must study the bee, not in books only, but in the hive itself, for though it is good to read of what other eyes have seen, it is better to see for ourselves.

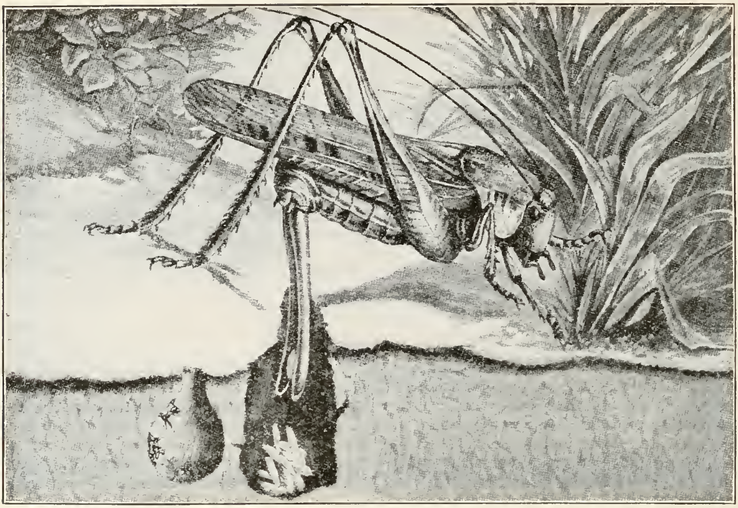
HOW INSECTS GUARD THEIR YOUNG

THE noblest thing in all the world is your mother's love for you, and this beautiful thing, without which the world could not have been, runs through creation. The great love which moves a mother to live or die, if need be, for her children, has its root deep in the universe, and from this seed springs the happiness of our race and the future of all life.

It is really true, as Charles Dickens said, that it is love that makes the world go round. Throughout the animal world, as in the human race, runs this golden thread of love. Even the fierce spider, which gobbles up her husband, is a loving mother to her children; the savage crocodile valiantly defends the eggs she has laid; the cold-blooded serpent, which will kill every other living thing, coils her form around the eggs from which her children will emerge. The mother bear is never so much to be feared as when her cubs need defending; the mother elephant is never so skilful and clever as when her baby gambols clumsily at her side.

Yet crocodile and bear and elephant, admirable as they are in motherhood, are not more admirable than the humble earwig, and not so laborious in their nursery duties as the bee and the ant and the wasp. Such insects, indeed, rank next to mankind as wise and loving parents. All that they do in planning and organizing their lives is prompted by the love of their little ones. The homes they make, marvels of accurate design and finish, are not for themselves, but for their helpless young.

We remember that many kinds of insects never see their children, and we ask ourselves, can it be love for their unknown little ones which prompts these insects to labor in constructing nurseries and laying up stores of food? Nobody can answer that with certainty. Man is wise, but he does not know all things. The senses of insects are not like our own, and we do not know how insects feel towards one another, whether love guides them, or what we call instinct. What is instinct? It is described by one of our highest authorities as "reasoning which



Grasshopper depositing her eggs in a nest under the ground

Spider mother holding up her egg to the sun, turning it round and round—A wonderful photograph taken by a French naturalist.

is organized, systematized, automatic." Let us bear that in mind, for it helps us to understand the puzzling question which rises to the mind. Can insects be said to love their children whom they never see? Some children's questions perplex the most learned philosophers, and this is one of them. Let us follow it up for a moment.

We know that millions of moths, butterflies, midges, and other winged insects die soon after leaving the chrysalis stage. These can never see their little ones, yet, in due season, in place of the parents the children appear. Many insects do not eat, cannot eat. Their mouths are imperfect. There is a food reserve in their bodies on leaving the chrysalis, and when that is exhausted they die. How does such a mother, which does not eat, understand the kind of food its caterpillar will require? How can the midge, whose life as a perfect insect is passed on the wing, know that its eggs must be laid in water? How does the lordly dragonfly know the same thing? Is it love for the children who will not be born until they themselves are dead which guides them, and prompts this marvelous selection of place for the eggs? The answer to this has taken a long time to discover, and it is a fascinating one.

It is believed that long, long ago the insects which now die as soon as they have laid their eggs lived much longer. Those of today, which cannot eat, had ancestors that could eat, and did eat, and may have lived long, and in that age insects would learn to choose the right food for their little ones. They would see the eggs hatch, and the little ones grow up and thrive when their food and their surroundings were favorable. Gradually they would learn by experience the place to choose and the kind of food to select. Those insects, profiting by experience, would leave large families behind, and these would learn to deposit their eggs in the right place. Those not profiting by experience would see their little ones perish, and would die without leaving families behind. In course of time, as the right and wise choice grew into a habit, the care of the parents for their young would become less and less necessary.

Mothers who live just long enough to lay their eggs and die

The process of laying eggs would be hurried on; the insect would live its life at a greater rate, as we say; and, a great amount of work being crowded into shorter space, the little body of the fragile insect would wear out sooner. So the lives of the parents grew shorter and shorter, until today many insect mothers have nothing to do but lay their eggs and die. Let us take one—the clothes moth. She never eats, because she cannot, yet there is not a living creature in the world that takes greater care in selecting a nursery for her young. She chooses a garment of wool or hair, and from her eggs come forth the tiniest of caterpillars. The garment chosen by the careful little mother is the luxuriant pasture of the baby caterpillar, which eats the fabric upon which it is hatched with as great a delight as a beautiful deer eats the grass of the park.

Bees and ants industrious little creatures

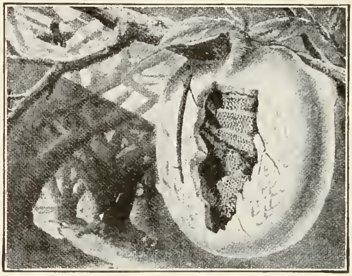
The queen bee and the queen ant are at the pinnacle of insect organization, but there are equal wonders to be found among bees and wasps which do not assemble in cities.

Here each mother has to make a little dwelling of her own, and it is strange to trace the different plans followed. Some of the wasps—our common wasps, for example—are social in their habits. They do not dwell in hives in the midst of a population which goes on from year to year, but create a family round themselves during the summer, and for a few months have a properly organized city, such as the first of the old-world beehives must have been. There comes a time in every year when all the worker wasps die; only the queens live through the winter. In the spring the queen seeks a site for her nest. It may be a hole in the ground, or a hollow tree, it may even be a position beneath the roof of a house. She chews woody, fibrous substances into a paste, which hardens into a sort of paper, and of this her cells are made. In each of these she lays an egg, from which a worker wasp appears in a very short time. Each worker at once begins to build new cells, and to help its mother with the labor of the home. The nest grows bigger and bigger, tier upon tier. In each cell the queen wasp places an egg. More workers are born, and when all is ready the new queen wasps and the drones are hatched. These fly forth and do not return. The labor of the home is completed. The workers have done their task. They have seen the queens and the princes depart, and they are ready for death.

Many kinds of homes are made by wasps and bees whose organization runs upon these lines. Some of the wasps hang splendid nests from the boughs of bushes and trees. The queen begins the work; the workers help her to finish it. The best example of this kind is that of the wood wasps, of which there are many species. One kind of wood wasp has so many children that the united labors of all produce a nest five feet in length. What an enormous structure to be made by such little insects!

Another interesting nest is that of what we call the solitary wasps. Here the mother wasp has the entire responsibility of providing for her family, and she makes the nursery in all sorts of places. It may be a little home tunneled in sandstone, or in a

Eggs of the common bumble-bees in their underground nests.

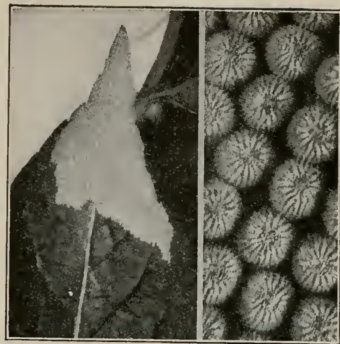


The mud nest of a solitary wasp, showing the comb in which it lays its eggs.

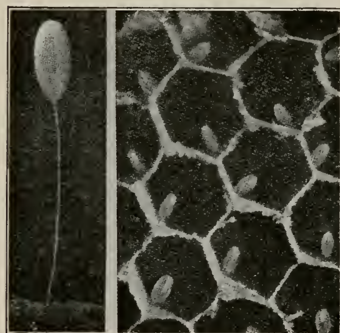
The carpenter bee's house of many stories in the branch of a tree.

mud wall, or in timber; sometimes advantage may be taken of an inviting keyhole. The house may be fashioned of paper made from wood or fiber, or of mud, or even of little pellets of sand cemented together by a fluid from the mouth of the insect. An example that we may all study is the common wall wasp.

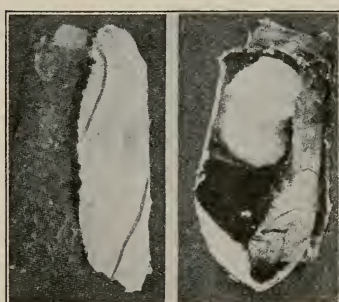
She makes her cradle in a wall, in which she constructs a tunnel, and lines it with paper, forming the snuggest little dwelling imaginable. Here she lays her egg. The mother will not be there when the larva leaves the egg; she will never see the little creature for which she is making a home, so she must prepare a food supply to last it through its infant life. Bees can make honey, wasps cannot, so the wasp must provide an artificial food supply. This is done in an extraordinary way. The mother wasp attacks another insect; it may be caterpillar, spider, or moth. Now, if the insect were simply walled up in the nest until such time as the wasp grub hatched and could eat, the prisoner would die and become poisonous. To prevent that, the wasp stings it in a vital place. The wound paralyzes the insect so that it cannot move, and cannot feel any pain. Paralyzed and insensible, the insect will retain just enough life to last until the young grub emerges from the egg of the mother wasp, and its body will be there ready to form a meal for the little creature emerging into life. The cells stocked by a solitary wasp may contain a number of such victims, each cell possessing a supply of food sufficient to last the infant until it passes from the larva stage into a complete wasp. The idea of leaving a wounded insect alive and lingering in this way seems horrible to us, but there is consolation in the thought that the victim in-



Thirteen hundred moths' eggs on a leaf, and eggs largely magnified.



The lace-wing moth's egg on the end of a stalk, and wasps' eggs in a paper nursery.



The cradle of a bee made from a leaf, and a grub feeding in it.

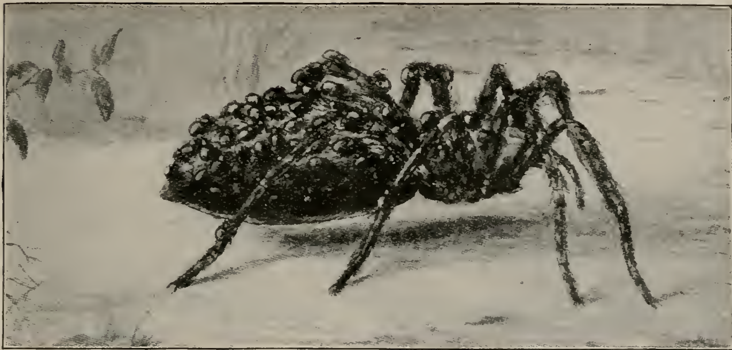
stantly loses all sense of pain, and knows nothing of what happens. Insects using sting and poison are unerring in their aim. They know exactly where to strike, and, as it is a great nerve-center which is maimed, there can be no feeling or sensation afterwards.

The solitary bees have prettier ways than this. They leave honey for their babies, and leave it in models of skilful contrivance. When we see holes in the rose leaves—clean-cut, semicircular holes—we know that one of the leaf-cutting bees has been there for a cradle. Very cleverly she makes a tunnel in the ground or in the trunk of a tree or in a wooden post; then she flies to a rose leaf or a willow leaf, hangs by her legs to the edge of it, and with her strong jaws cuts away a piece the exact size required. Just before she makes the last cut she sets her wings in motion, and hovers steadily in the air. Then she flies to her tunnel, shapes the piece of leaf like a thimble, and lines the bottom of the boring with it. When it is made quite secure, she flies off to the flower-bed, collects nectar and pollen, kneads a little loaf of "bee-bread," deposits it in the leaf, and lays an egg in the larder-cradle. Next she cuts another piece of leaf, and with this roofs over the cell. Afterwards she cuts still more leaf, and with that makes a second cell, which she rests on top of the first, the bottom, shaped like the nose of a thimble, fitting perfectly into the hollowed roof of the one below. With great care she seals up all the places from which honey might leak, and to this cell also she gives an egg and a supply of pollen and honey. From six to ten cells, one on top of another, may be made in this way, until the shaft is filled with cradles. The top of the tunnel is then covered over, and the bee flies away, knowing, we may imagine, that she has done her duty to the children that are to come to life in this marvelous home she has made.

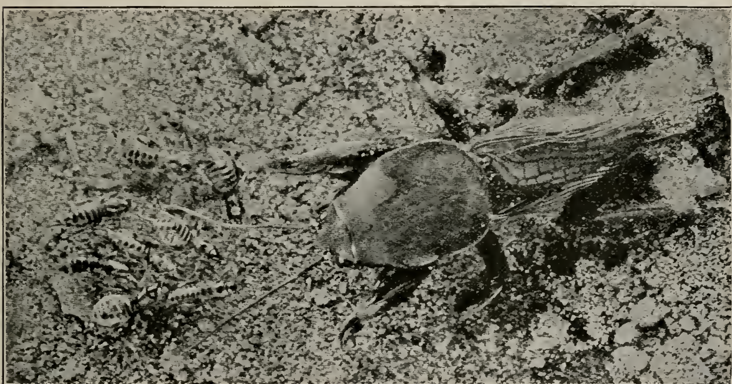
THE WONDERFUL HOUSE THAT THE CARPENTER BEE BUILDS

Carpenter bees make still more elaborate homes. They bore deep tunnels inside the trunks of trees. At the lowest depth a little chamber is prepared. Here the bee deposits an egg with a proper food supply. Then the chamber is tightly roofed over with water-tight paper made by the bee from the wood of the tree. Above this first chamber a second is made, and this in turn is stored with an egg and food before the roof is put on. The roof of the cell below serves for the floor of the chamber above. It is a beautiful piece of work, about as thick as a cent, and made in rings, the outer ring being cemented to the wood of the tree, the inner rings gradually filling up the opening until the cell is completely closed. The chewed wood of which the ceiling is formed is rendered watertight by a fluid from the bee's mouth, so that there is no danger of the honey stored in one cell leaking into the one below and leaving the little tenant to starve. A carpenter bee may make two or three such tunnels, each with from seven to eight cells, so that we may imagine with what great determination she works for the good of the children she will never see.

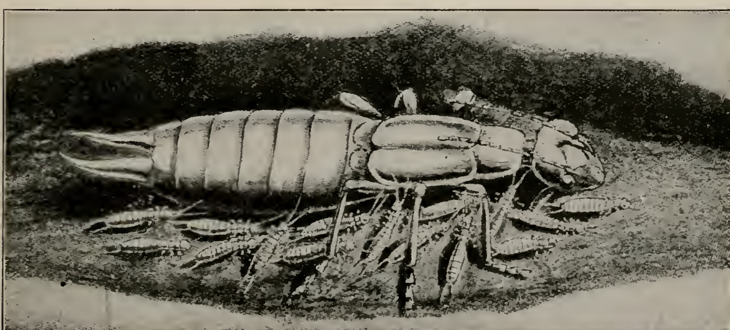
The leaf-cutting bee is not the only insect to employ leaves for the cradles of her young ones. Leaves form the homes of many of Nature's tiny children; some tiny moths pass their caterpillar stage actually within leaves, tunneling the leaves and eating the parts they excavate, just as the great fat larvæ of the wood-boring beetles eat the pulped fragments of wood that they gnaw in the interior of tree trunks.



Mother spider carrying her young



A mother mole cricket with her family



An earwig guarding her little ones

The clever cradle made by a mother beetle from a leaf

But we come now to work upon leaves performed not by the larvæ but by their parents — the leaf-rolling beetles. These beetles make cuts in the leaves as the bees do, but for a different purpose. Beginning at the top of a leaf, they bite a semicircular track down to the tough center of the leaf, which we call the midrib. Half the leaf, detached from its upper support, hangs limp, and this half is rolled down by the beetle into a series of coils, which hang parallel to the midrib. Then the second half of the leaf is cut in the same way as the first, but is wound round the first half. The beetle lays her eggs inside the folded leaf, fastens down the outer fold upon the first, seals up the bottom of the home, then gives a sharp bite to the upper part of the midrib, to make the entire leaf limp and easy for the baby beetles to eat when they are hatched. Then her work is done. The little ones will never see their mother, but when they issue from the eggs they will find the wilted leaf that she has prepared, and will find it not only a cradle but food. They will eat and be merry, change from grubs into the pupa form, drop to the ground, and bury themselves in the soil for the winter. Then, in the spring, they will come forth as beetles, and the females will attack other leaves.

But it is not all insects, of course, who never see their children; many insect parents have the joy of seeing their babies about them. Some spiders carry their eggs about with them in a little yellowish-white bundle of silk, and great is their distress if they misplace it or if it is taken from them. When the little ones are hatched, the mother keeps careful watch over them, and shows the most desperate courage in defending them.

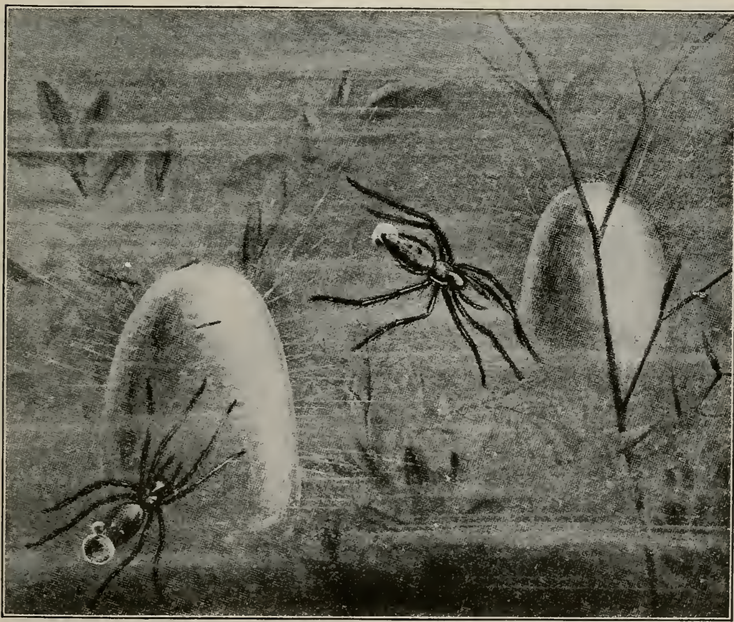
Some spiders are not by any means content merely to guard and guide their babies, but actually carry them about on their backs, so that they may not stray into danger. Two kinds of spiders have really wonderful homes for their young. One is the raft spider, which binds leaves and fragments of weed together, and floats it on water. The eggs are carried on this raft, and the young ones, which in due course will pop out to dine on land just as freely as they will run upon the water, are actually born upon the deep! The water-spider constructs a lovely little palace of silk actually beneath the water, fills it with air carried down from above, and in this beautiful dwelling lays her eggs. The young ones are born in a silken diving-bell, and the faithful mother rests in her fairy dwelling with them, going aloft only at intervals to catch food and bring down fresh supplies of air.

We must all wish that the gnat or mosquito, were not so clever and careful in her treatment of her eggs, for while the many gnats merely bite and cause one to smart, some of their relatives carry poison germs which kill thousands of people. The female gnat constructs a raft. She may make use of a piece of floating leaf, or may make a raft of the eggs themselves. The eggs are cigar-shaped, and are glued together to the number of 200 or more, and stand upright in a solid mass, the heavier part pointing downwards, the light part at the top. Owing to the tiny spaces between the tops of the eggs, it is impossible for them to sink or get wet. If they are driven under water a bubble of air accompanies them, forming a shield for the tops of the eggs, and so keeping them dry. In places where these mosquitoes cause disease, men fight them by covering the water with petroleum, which, being lighter than water, floats on the

MARVELOUS HOMES OF THE WATER SPIDER

The water spider comes up for an air bubble

And carries the bubble to its nest



The silk air chamber, in which the water spider lives down in the water—Spiders bringing down fresh air from the surface

surface, so that when the larvæ come to the surface they cannot breathe, and die at once.

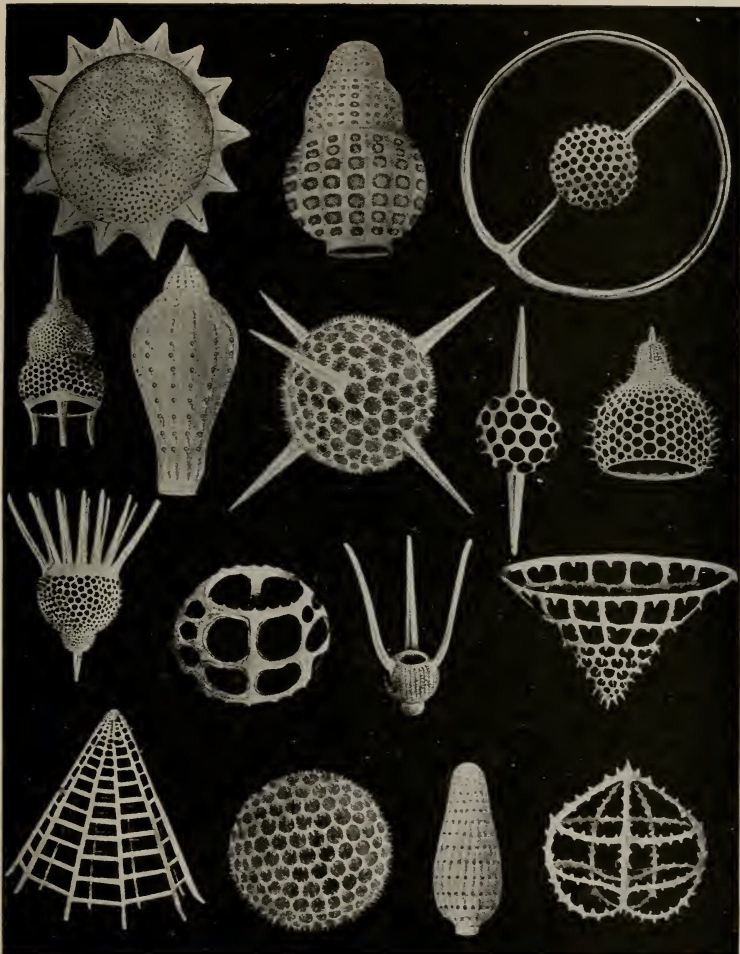
As the great water-beetle is the monarch of the pond, we might expect her to lay her eggs in the water, as the mosquito does; but she does not. The mother beetle weaves a wonderful cocoon, which contains upwards of a hundred eggs. This cocoon she places on the soil by her pond, carefully hidden, in such a position that the larvæ, when hatched, can enter the water as soon as they desire. The larvæ pass their infancy in the water, but to make their change into the chrysalis stage they have to go ashore again, and bury themselves in the damp earth, finally to emerge as winged beetles, equally at home in the air and on the surface of the water, handsome and interesting to all but the living things which they seek as prey. The common smaller water-beetle makes for herself a cocoon of silk for her eggs actually in the water. The eggs do not need their gauzy little yacht to enable them to hatch, for they come to life in the water; but the silken covering protects them from carnivorous creatures, and that is why the painstaking mother labors to prepare this dainty cradle for them.

So far we have found that only female insects look to the care and upbringing of the children, but we must note that in certain sea-spiders known as the *Pycnogonida* the males are the nurses. In these the males carry the eggs attached to their legs until the baby spiders are hatched. Generally speaking, however, the mother is solely responsible for making the home and providing for the future of the little ones. Even when the mother insect does not trouble herself with the task of rearing her family, she has to undertake the great responsibility of finding the exact position in which her children will thrive. The mother scarab, or sacred beetle, of which our common dor beetle is a cousin, displays the greatest skill in her effort to preserve her little one from death before it is old enough to withstand the rough usage of the world. These beetles, which the ancient Egyptians regarded as sacred, eat unpleasant forms of food, but prepare a special compound for their young. The food is formed into a little sphere, and the small egg is placed in the food, but at the extreme end of the mass, and at that end a tiny opening is left, not actually bare, but guarded by a fine lattice-work, just enough to admit air.

The rest of the food supply is coated with a hard substance resembling clay, and the whole is placed in a tunnel under the ground. Unless the site were carefully chosen, the food-mass encased in clay, the heat from the burning sun would dry up the ball of food, so that the grub would starve in its cradle. A French naturalist, M. Fabre, has given us the remarkable story of this insect in full, and for the first time has shown that the ancient Egyptians were right in believing that the little scarab comes from this ball of matter.

It is wonderful to find this sense of duty in such lowly creatures, and we find it running widely through the insect world.

BEAUTIFUL FORMS OF SHELL SAND OF THE SEASHORE



When we examine the sand on the seashore it reveals millions of little shells so tiny that we need the help of a microscope to see them. These little creations are marvels of form and color. The illustrations above show a number of forms as revealed under a powerful microscope, while the color shadings are so wonderful that man with all his skill cannot imitate them. Many of the cliffs and rocks in the vicinity of the English Channel were formed from these sand shells which through millions of years were gradually changed into solid forms.

ANIMAL LIFE IN OCEAN DEPTHS

INHABITANTS OF THE DEEP

We know that all life began in the sea, and we have read how life came out of the sea to cover the land. But life did not leave the sea forever. There is still more life in the depths of the ocean than on the land. The sea teems with unnumbered forms of life—life as simple as that which first swam in the waters, and life as wonderful as that of the whales and dolphins and seals. There are fishes that sail through the air high enough above the water that we call them flying fishes. There are fishes that are found out of the water. There are fishes that build nests at the bottom of the sea; and in cliffs and mountains we find myriads of skeletons of tiny creatures that once lived and breathed on the ocean-bed. In these pages we read of the many wondrous forms of life in the seas today.

NOT the wisest men on earth know the full story of the sea and its wonders. How can they? They have to seek knowledge from the things that their dredges bring up. That is as if we set to work to examine some great, deep lake by bringing up things from its depths in a teaspoon. However, patient work is constantly bringing new learning to us. We know that there is no place in the ocean where life is not possible. The waters of the equatorial regions and the seas of the temperate zone abound with life, but so also do the silent waters of the frozen Arctic Circle.

Nature will have no blank spaces. There is a place for everything, and we find everything in its place. We find, swimming upon the surface, creatures which cannot descend. In the middle depths we find fish which cannot come to the surface lest, without the proper pressure of water upon their bodies, they should burst. Those same creatures cannot descend beyond a certain level; and below these there are creatures which never see the light, fulfilling in the unlit depths of ocean the purpose for which they were created.

For the present it will be interesting for us to glance at some of the lowest forms of life in the sea. We shall find it as wonderful as anything in the whole of Nature's fascinating story. Let us consider the marvels of that class of tiny organisms called infusoria. They exist in fresh water and in the water of the sea. In a single cupful of pond-water, such as certain infusorians love, there may be more of them than there are people in the whole world. The rate at which they grow is astounding. One infusorian breaks up into two; two become four; four become eight; eight become sixteen, and so on, almost as we watch.

Given the proper temperature and nourishment, a single infusorian may become in four days the ancestor of a million like itself, in six days of a billion, in seven and a half days of a hundred billions. From that tiny speck we have in seven and a half days this countless host, weighing over 200 lbs. Of course, the numbers do not work out like this, for there are merciful checks, or the whole earth and its seas would not hold the creatures that are born.

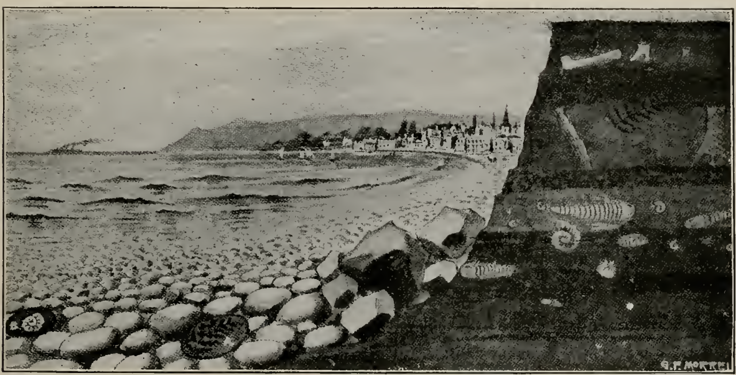
Floating upon the surface of the sea, and stacked high over its bed, are countless billions of these and similar tiny creatures, dead and living. Of what are the beautiful chalk cliffs of England composed? Of nothing but the shells of the tiniest little creatures, which we call foraminifera. They were all living creatures millions of years ago.

They were born and had their day, and they died, piles upon piles of

SECRET OF THE PAST LOCKED IN A PEBBLE

The wearing down of the cliffs in which lie buried creatures of ages past—the top layer hundreds of thousands of years old, the bottom layer a hundred million years old.

At high tide the waves beat against the cliffs and roll the great boulders about, wearing down the corners and edges into the shape of pebbles.



THE PEBBLES AS THEY LIE ON THE BEACH TODAY, OFTEN CONTAINING A FOSSIL WHICH MAY BE DISCOVERED AND PRESERVED BY CAREFUL SPLITTING OF THE STONE

The fossils in these pictures are, of course, shown very large. Those marked A and B help us to follow the history of one pebble.

them, and their limy shells turned to chalk. And other white cliffs, which will some day rise above the waters, are still being built up beneath the sea today. The tiny specks of life in their little shells are still being born, and are still dying down in the sea, and they are forming ooze which will some day be solid chalk. It would take about ten millions of them to make a pound of chalk, but there have been enough to make millions of tons of chalk.

THE LITTLE ANIMALS THAT BUILT UP THE STONES OF PARIS AND BERLIN

Some of the greatest mountain ranges, the Alps and the Balkans, consist largely of the shells of little creatures like these, called nummulites. Among the greatest wonders in the world are the Sphinx and the Pyramids in Egypt, built of dead nummulites. They grew in seas which ran where dry land now is. They formed the Arabian chain of mountains; from these mountains men cut the great blocks of which the Sphinx and Pyramids are composed. Paris is built of stone from a similar source, and Berlin stands upon foundations made up entirely of the skeletons of tiny animals.

In view of all this, we shall not be surprised to learn of the wonders of the coral builders. These are very tiny sea animals, which appear in their glory only in the warm waters of sunny seas. We all know what coral is, the beautiful pink polished substance of which necklaces, bracelets, and scores of pretty ornaments are made. We know what coral is, but the way in which it is made was for two thousand years a mystery.

THE LITTLE CORAL BUILDERS THAT WORK DOWN IN THE SEA

Long, long ago, men had been in the habit of bringing it up from the sea in nets and by other means. The common fishermen could not be expected to know a great deal about its composition, but the wise men thought they knew more, and they all agreed that coral was simply a sort of rocky flower grown in the sea. But how could a flower be hard? That was quite simple, they said. The fishermen told them that coral, when in the sea, was quite soft like any other flower, but that as soon as it reached the air it became as hard as rock. And for ages that was believed. But a man who wished to know more sent down a diver, who found, of course, that coral beneath the waves is as hard as coral above the waves. The good man could not believe the word of his diver, but went down in the water to see for himself.

We know now that the coral builder is one of the tiny, tireless workers of the deep. The coral animals are as numerous as the stars of heaven. When born, they are quite soft, jelly-like little things. But they have the power to extract carbonate of lime from the sea-water, and to build with it the most wonderful structures. As a bee makes its wax, or as the oyster builds its shell, so the coral polyps make lime from their food, building up slowly and laboriously a most beautiful and curious framework.

THE WONDERFUL ANIMAL WALL THAT RISES FROM THE BOTTOM OF THE OCEAN

Some form structures, looking like flowers. The colors are not always the same. There are browns and blues and greens, as well as the more common pink. This coral is not made as a bird makes its nest, not as the mud plaster in which the rhinoceros loves to bury himself in a swamp; the coral is part of the coral animal itself. It issues from the soft interior of the little animal's body, and is its stony covering or skeleton.

Countless hosts of coral polyps working together join their skeletons or coverings to each other. They build up from the bottom of the sea, until they reach the top of the waves. They make great reefs or barriers in the sea where, before, the waves flowed unchecked. The coral polyps build islands. They put a great ring of coral around a tract of water, and make a lake within the boundaries of their work. In places where they are most numerous they quite change the character of the sea. The reefs and islands are the actual coverings of millions of coral polyps' bodies. They become solid rock forming dry land for thousands of miles in the sea. It is a most wonderful work that these little animals do by their own efforts.

We know how very difficult men, with all their skill and fine tools, find it to build a lighthouse in the sea, but here these tiny animals, working in the depths of the furiously tossing waves, build structures which have no likeness in the world. One of their works consists of a barrier reef along the shores of New Caledonia, 400 miles long, and another, along the northeast coast of Australia, 1000 miles in extent. As a great man points out, this means a work by these tiny things beside which the wall of China and the Pyramids of Egypt are like children's toys. The work has been going on for many ages, it is going on today. Of course, the result is often very serious to ships, which run on the coral reefs and get wrecked. But that should not happen, for we have charts of the seas to guard our sailors against wreck in such a manner.

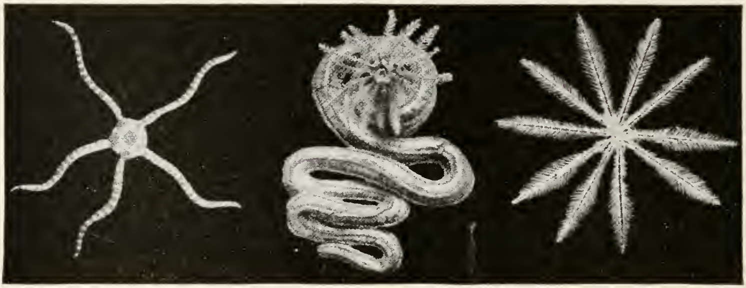
Living and building and dying in the blue sea

If they do damage in this manner, the coral builders are friends to mankind in another way—they provide homes for men where only the angry sea once appeared. Sea animals of various sorts bore into the coral and loosen it, so that the waves break it up. The great waves pick up huge blocks of the loosened coral, and throw it high up on the reefs, grinding much of it to powder. Shells and sand collect and are ground up together by the action of the waves. The powdered mass collects in the crevices of the reef, and presently seeds blown from afar, or carried by the sea, or brought by birds, take root in the soil that has been slowly forming. Entire trunks of trees, that have been torn up and carried down the rivers and out to sea, find a lodging here. With these trees come small animals, like lizards and insects. Trees grow, sea-birds settle; tired land-birds, blown out to sea, take rest; and at last man comes, to find trees and fruit and birds and other forms of life. Here is a home ready made for him. He cuts down the trees and builds himself a house, and there we have a new part of the world prepared for human habitation. But the creators of it were the myriads of coral animals, living and building and dying in the blue sea.

The living flowers that grow on the living walls of the sea

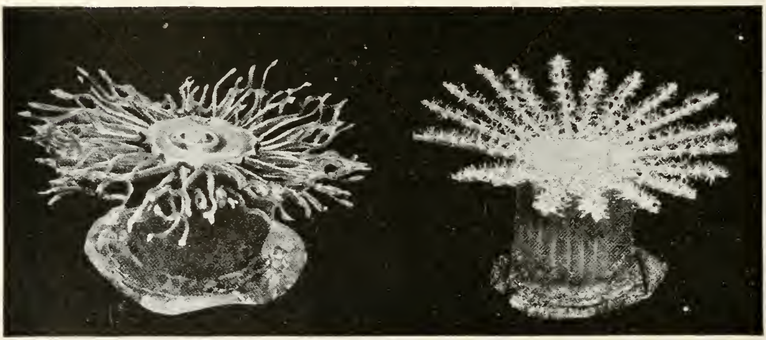
Growing on the coral reefs and adding to their beauty, we find a great many sea-anemones. At first sight we should say that these are vegetable growths. Their very name suggests it.

The wood-anemone we all know, the pretty flower of the country woodlands. Surely, then, the sea-anemone must be the wood-anemone's cousin, growing in the sea? But the anemone of the sea is an animal, which can kill and eat other forms of animal life and by some process of instinct too mysterious for us to understand, can enter into partnership with other animals, just as birds enter into partnership with crocodiles, buffaloes, and rhi-



The brittle starfish A big sea slug Delicate feather starfish

A group of sea anemones which resemble flowers, but which hunt and kill



These pictures of sea anemones have their mouths open and tentacles spread out ready to grasp the tiny animals of the sea upon which they feed. They hunger, and hunt and kill living prey to satisfy their hunger. They take into partnership other animals like the hermit crab, which helps them to obtain food. The Portuguese man-of-war is a beautiful thing, but stings painfully.

noceroses. This animal-plant or plant-animal, as we think it, grows in the most elaborate and gorgeous forms. A fairy wand could not create more charming pictures than the sea-anemones present. Some of them appear to have a sense of sight, for what look like eyes appear. They depend, however, on touch for their food. They have long, sensitive feelers, which look like petals or fringe. These, when anything fit for a sea-anemone to eat touches them, close like a flash upon it, and draw it down the tube leading to the sea-anemone's stomach.

Let us watch them in a sea aquarium. The sea-anemone, glistening and gay, grows at the bottom of the water, or on the side of the glass, like some extraordinary fringed mushroom with its head the wrong way up. There is nothing to suggest that this is a hungry little animal. But wait!

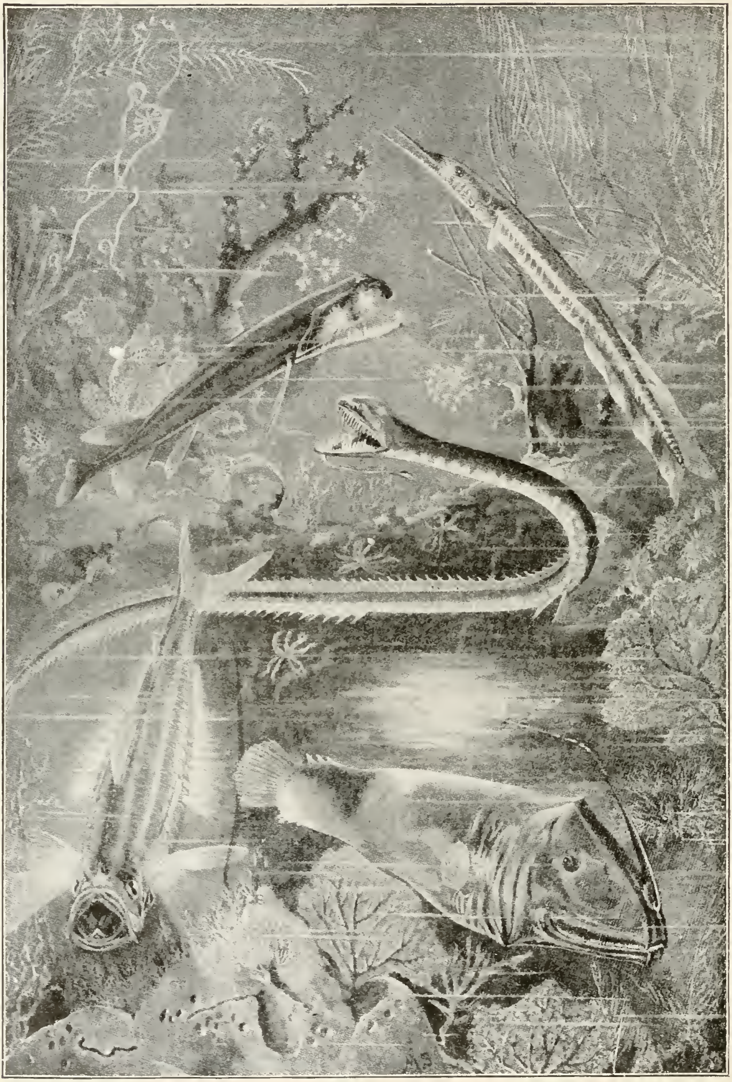
How the anemone lives with the crab, and the crab with sponges

A lively shrimp darts through the water. The tentacles of the anemone are instantly all of a quiver, ready to catch the little shrimp. The shrimp's instinct or experience tells him what that means, and he darts away if he can. But he cannot always do so. The sea-anemone must live and have his shrimps, or other form of food, and the tentacles close rapidly in, causing the sea-anemone to shut up like a flower which is going to sleep for the night. And if the effort made is quick enough, the poor shrimp is encircled by those terrible tentacles, and drawn in to make a good meal for the deceitful fisher.

There are countless sea-anemones growing upon our seashores. Some look like rosettes, others like bobbins with a frayed, fringed top. The fringe of tentacles lies widely expanded, and we should never dream how quickly they can move. Let us touch the top of the anemone with a finger. It closes at once upon our finger, and we feel that each little spike of the fringe is roughened at the end, and gives a distinct pull at our finger, like the rasped claw of some insect. They are not strong enough to take in our finger, but they have received the necessary impulse which sets them at work. The anemone shuts up, believing—if we may use that word—that it has caught a meal, and for some minutes you will find that it will not attempt to reopen.

It is a humble, lowly form of life, yet there seems so much purpose and set plan about the way of the sea-anemone that we are amazed and bewildered at such apparent method and skill. But the wonder only begins here. The partnerships of the sea-anemone are the most wonderful feature of its life. Let us consider for a moment Messrs. Crab, Anemone & Co. The hermit crab, while a vicious, quarrelsome little rascal, has no shell to cover his tail. That is the spot which his enemies attack. His one hope in life is, therefore, to win and retain a secure covering for his unprotected tail. He and the sea-anemone seem to come to an agreement. The sea-anemone affords him just the cover that he needs for his tail, and he in exchange carries the sea-anemone about on his back.

The tentacles of the sea-anemone are towards the nippers of the crab, and when he goes in pursuit of his prey, the anemone helps to kill it. The anemone has stings which paralyze or kill a little living animal. The crab has, therefore, a powerful ally to help him in killing his food, and as he eats, the anemone shares his meal. It is a profitable partnership. The crab gets his tail protected; he is largely hidden from his enemies; he is hidden, too, from the things that



No man has been to the depths of the ocean in which such strange creatures as these live; but we know that the bed of the seas swarm with phosphorescent fishes which live in great depths.

he desires to attack. The sea-anemone is carried about, and is kept in constant touch with an ample supply of food. Thus we have a life partnership between the simple-looking plant-animal and a desperate warrior who is always battling.

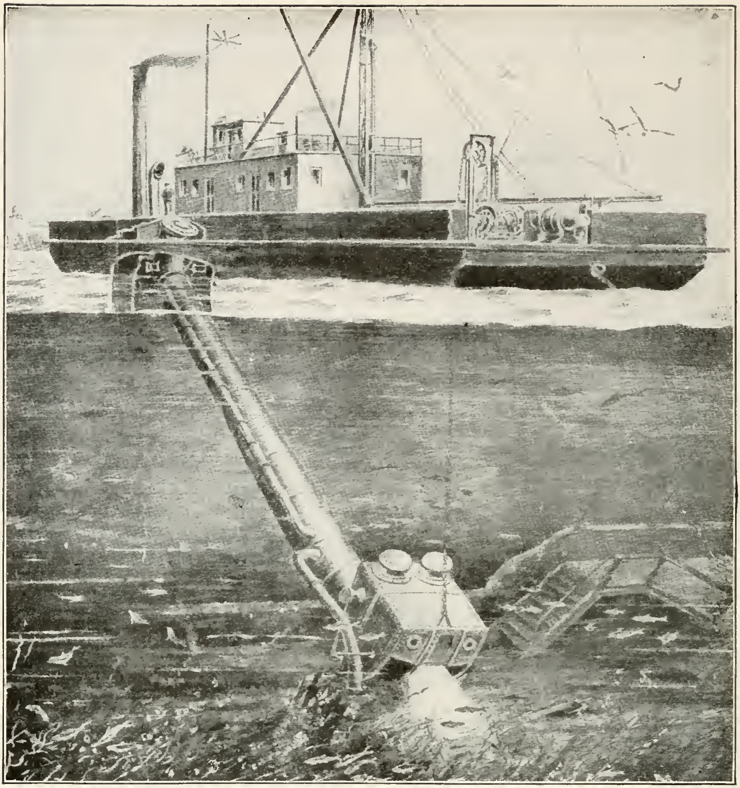
The study of sea-anemones is a most interesting one, and one which all who reside by the seashore can pursue. Think of them not as plants, but as animals, of which the larger will swallow a cent piece, or perhaps a shell the size of a saucer, and then divide into two living animals rather than lose the booty it has managed to secure.

The sea-anemone is not the only sea animal with which the crab goes into partnership. There is a certain sponge in which he makes his home. We know that sponges are not vegetables, but animals. They admit the sea-water through the canals in their bodies. From this they extract tiny forms of life for their food, and at the same time take the oxygen which the water contains. That is the way fishes breathe. They have no lungs, except in rare cases. They have gills, over and through which the sea-water washes. These gills take the oxygen from the water, and pass it into the bloodvessels, so that the fishes may breathe as we breathe. The method is, of course, very different, but the purpose and result are the same. Well, that is the way in which the sponge, no matter what its name or size, breathes and feeds and grows.

In some of the channels running through the sponge the hermit crab may make its home. Higher up in the same channel may be discovered a little shell, and some other tiny animal. In this collection we have the history of four forms of life. First of all the hermit crab pops his naked tail into the empty shell left by a growing whelk. Then comes a young sponge, sent forth on its life journey by its parent. It settles upon the whelk shell in which the crab has sheathed his tail. There the sponge grows and grows until it quite covers the shell, but it leaves open a channel by which the crab can enter and depart. Then as the sponge and the crab grow bigger they take into partnership a little assistant, which is admitted into the interior of the sponge, simply that it may devour any refuse which may collect in the home of the crab. Even such humble things as crabs and sponges have to guard against unclean homes; thus they are more careful than many human beings. And that is why we find the interior of the sponge occupied by a shell, a wormlike animal, and a crab.

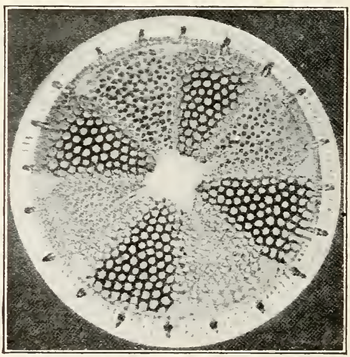
Where the corals abound, fishes of the most brilliant color are always to be found. The fishes protect themselves by becoming colored like their surroundings, just as the animals do. But swimming with them are marvels of colored jelly, as they seem. They are the jellyfish. We may all see jellyfish at the seaside when the tide goes out. Better still, on a favorable day, we may see hundreds of them floating on the sea as we go by steamer. Those round our coasts look like great white or transparent leaves, with a little dash of red in the center, as though they had been darned with colored wool. We do not have the jellyfish of brilliant color. They belong to the warm seas of the tropics. But the nature of all jellyfishes is much the same.

Those of the tropics give off a brilliant silvery light at night, which helps to make the sea like a gleaming mirror of liquid metal. Others are not so attractive. If we catch one and lay it on a piece of blotting-paper for



A NEW WAY OF EXPLORING THE OCEAN BED AND RECOVERING LOST TREASURE FROM WRECKS
The explorers go down a tube, five feet wide, to a kind of diving bell, fitted with a powerful searchlight.

The tiny specks of life in the sea, known as diatoms.



One diatom, magnified over a quarter of a million times.

examination, we have to be very quick with the examination, for the jellyfish is composed largely of water, and it simply dries up before our eyes. They are not nice things to handle; they can sting very badly, as all sea-bathers know. The scientific name of the jellyfishes and their kin is taken from the Greek word which means nettle, and sea-nettles is an English name for the jellyfishes that sting.

By far the most alarming of the sea-nettles is the Portuguese man-of-war, or *physalis.* This looks like an inflated bladder, six inches long. Beneath it streams a number of organs, important to the animal in gathering and distributing food. The tentacles which we most wish to avoid are those which carry the stings. These are intended to numb the prey of the physalis, but woe to the man who comes in contact with them. They flow out from the body of the animal for some feet into the water, and are heavily charged with stings and a poisonous fluid. The merest touch from them will raise a white swelling on the hand, and for long afterwards the hand and arm experience an aching pain, which gradually extends to the muscles of the chest, causing some trouble in breathing.

The sea-anemones, the corals, the jellyfish, and many other plant-like sea animals, all belong to the same family. We have another interesting family, including the starfishes, sea-urchins, sand-stars, brittle-stars, feather-stars, and so forth.

THE WONDERFUL STARFISH THAT WALKS ALONG THE BOTTOM OF THE SEA

We may see hundreds of star-fish at the seaside. There is not a simpler, more innocent-looking thing to be found by the sea than the starfish, particularly that commonest of all, the five-fingered jack, or crossfish. Yet it is really a rather wonderful creature. Its organs are in the center of its body, and the fingers branch out from that center. The fingers are really the legs, for there are tubular feet underneath them by means of which they walk as comfortably along the sea-bottom as we walk along the beach.

The starfish has a terrible appetite, and oysters, mussels, scallops, and other shell-fish are its food. It seizes its prey with its long and strong arms or fingers, and, no matter how powerful the shell may be, by persistent pressure the starfish manages to force it open, and eat the fleshy interior. Fisherman hate the starfish, and, when they catch them, tear them in two and fling them into the sea. That is not only cruel but stupid. Though you tear a starfish in halves, the animal can recover. Each of the two halves heals and grows new fingers, and, instead of a dead starfish in two halves, you soon have two starfishes, fully equipped and very much alive.

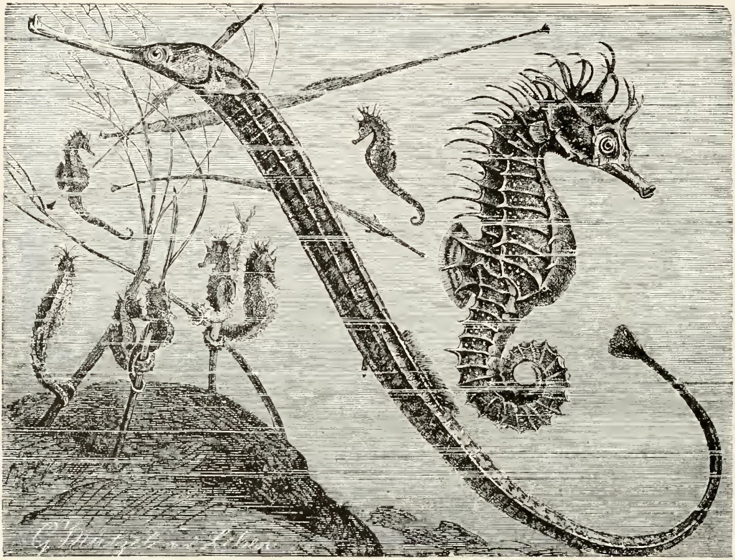
THE SEA-CUCUMBER THAT THE CHINESE PEOPLE LIKE

What we call the sea-cucumber is, like all the other things we have been considering, an animal. Its other names are the sea-pudding, the sea-slug, and the trepang. It has the same sort of feet that the starfishes possess—suckers which protrude from tubes, and can get along over places which seem quite impossible to it.

The common name of the sea-cucumber suggests the idea which its appearance presented to those who bestowed the title upon it. The Chinese consider it a great delicacy for the table. There are many kinds of sea-cucumbers, and the rarest bring quite big prices. It does not sound nice to eat sea-slug, and we in this country are content to leave it to the Chinese.

The mystery of the lowest forms of life in the sea

We have now glanced briefly at some of the lowest forms of life in the sea. It is quite as wonderful as life among the higher animals. We do not expect much of animals that seem to be no more highly gifted with life than plants; but, as we have now seen, there is a mystery and fascination about these lowly creatures sufficient to make even the wisest men marvel at their habits.



SEA HORSE AND PIPE FISH

One peculiarity of the sea horse is that the apex of the head is at an angle with the rest of the body. Its superficial resemblance to the knight of the chess board is striking. It is chiefly found in eel-grass or other vegetation and is wont to twist its very prehensile tail around some stalk and there remain in an upright position.

TIGER OF THE DEEP

ON ACCOUNT of its size, activity and strength, the Bengal Tiger should undoubtedly share equal honors with the lion, which has been awarded the kingship of all the land animals for a long time. When, however, we come to consider the headship of the innumerable tribes of the ocean, we are under no difficulty whatever, and the more we learn about the monarch, the less do we doubt his right to the title. True it is that to most people it is sufficient to call the "sea-shouldering whale" the sovereign of the seas, after man, and the idea that among whales there are many varieties does not disturb the placid verdict.

Only naturalists as a rule, and those who have dared to hunt and slay this gigantic sea-mammal for the sake of the spoil his vast carcass yields, realize how far in every detail the sperm whale towers above every other member of the brute creation. Only in the one factor of size does he yield place to two other kinds of whales, the gigantic Bowhead or Arctic whale, and the vast Rorqual, known to whalemen as the Sulphur Bottom. Both of these occasionally produce specimens half as large again as the greatest Sperm whale ever measured, which was about 70 feet long, 50 feet in largest girth, and weighed in the neighborhood of 150 tons, or as heavy as twenty-five large elephants.

But the Arctic whale and Rorqual have their only preeminence in size; they are peaceful, unaggressive, stupid, and slow, while they have no weapon for attack or defence save the enormous tail-fin or flukes.

The Sperm whale, on the other hand, has all the highest characteristics of a warrior. He is brave and well armed, for his chief feature is his enormous head with its huge, pendent lower jaw, a shaft of bone, often reaching 20 feet in length and bristling with teeth set sparsely on either side of it, and averaging six inches in length above the gum. They are conical and about six inches in their largest circumference, and fit into sockets in the upper jaw, there being no teeth there to oppose them.

Unlike any other whale known, the female of the Sperm whale is never more than half, more generally one-third, the size of the male. In most other whales the females are the larger. That mysterious substance known as ambergris, even now valued at $15 per ounce, is produced solely by the Sperm whale. Alone among all whales this wonder carries a great reservoir of liquid spermaceti in his head—pure, bland, snowy, and limpid until exposed to the air, when it concretes. Science has dethroned it from its high place among lubricants, for it has no properties not shared by pure lard or vaseline. But think of having 500 to 1000 gallons of that stuff floating around in a head—not as brains, for the brains of the Sperm whale are not larger than those of a bull. Practically blind, deaf, and without sense of smell, this lordly ocean monarch pursues his amazing way, and thrives beyond belief until he meets man

These wonderful creatures, alone of all the sea people, have no efficient foes save man and one another. Among themselves Sperm whales fight tremendously for the headship of a "school," and the vanquished ones are thenceforward condemned to roam the wastes of ocean solitary and morose. These "lone whales" are exceedingly dangerous to attack, if indeed they do not attack first, thereby playing havoc with otherwise well-laid plans.

But the knowledge of that fierce fact has never deterred the Yankee whale-fighters from attacking them. Indeed one hardly imagines any characteristic of a whale that would have hindered an old-time "whaleman" from New England from "sailing in" when prey was in sight.

A FIGHTING WHALE

A monster fighting whale had been twice harpooned and had gone off at top speed for several miles, drawing two boats behind him in his foaming wake. When the great mammal tired, at last with exultant shouts the boats' crews gained upon their prey and drew alongside while the mate hurled a lance its whole length deep into the leviathan's body.

"Starn all! Starn all!" he yelled a moment later.

With a will the men tugged at their oars, and the boats shot clear to avoid a great peril that threatened. From the extreme urgency of the mate's tone they guessed that the whale was about to "breach."

It needs a strong effort of the imagination to picture that dark, solemn sea, only lighted by tiny splashes of phosphorescent light where wavelets broke in obedience to some hidden suasion, or by an occasional, fleeting, brilliant band of light that marked the swift passage of some great fish through the highly charged water. And then, without a sound, like the sudden extrusion of some gigantic flame cone from the uncanny depths, there rose majestically a vast luminous body whose brightness poured from it in floods of light, revealing the black central mass; and, as it soared the light fell from it in glowing waves to the illuminated whirlpool from whence it arose. At last the leviathan fell, and at the impact a blazing sea rose in many a sudden fountain, an immense boom as of muffled thunder broke the awed stillness of the night, and over a great area wave upon wave of light rushed any whither and broke upon their fellows, until stillness and darkness resumed their momentarily interrupted reign.

For a few minutes the awe-stricken boats' crews sat at their oars unable to think, benumbed, not with fear, but bewilderment at this terrible manifestation of energy. After that brief space the sea-surface gave no sign of anything unusual beneath it, no sound save a faint moaning as of gathering wind afar off broke the cosmic silence of the night. Then a sound like a gigantic sigh broke upon their ears, and they saw, within a short distance, a greenish break in the dark surface of the waters, accompanied by a slight plashing noise as when a lazy breaker lolls upon a reef on a calm day.

But, slight as it was, the appearance roused them to instant energy, and with ready obedience to the hoarse orders given, they wielded their oars, while the boats both headed for the spot. Suddenly the long slender lance flew from the hands of the foremost boat-leader, and as if in instant response, both boats whirled about and sped away through the darkness at a speed of some ten miles an hour. It was evident, though, that the enormous effort made by the whale had not been without a certain exhausting effect upon him, for the speed soon slackened.

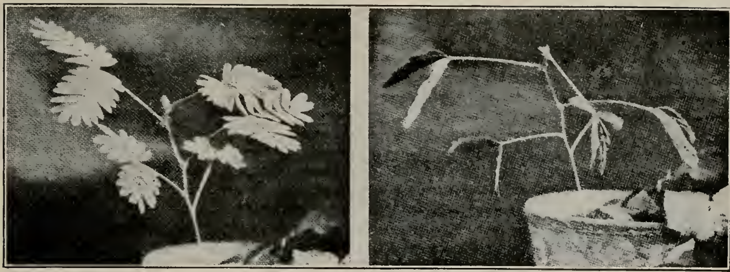
A NARROW ESCAPE

Then, without a moment's warning, the two boats suddenly rushed at each other, the boat-leaders in each just averting a frightful calamity by snatching up in their arms the two or three lances which were pointing diagonally from each bow. There was a hubbub of voices, a rending and crashing of oars, and the boats shot past each other as the whale, having doubled back upon his previous path, reappeared again with a commotion like heavy waves beating upon a rock. Nearly out of the water, with jaws wide open, he came straight for the boat, intent on biting it in half.

But the whalers bore in upon him vigorously, and again and again the lances flew into the dense blackness, fringed with green light, that marked the position of the whale.

Meanwhile the harpooners at the steer oars never for a moment relaxed their vigilance, swinging the boats this way and that, while ever keeping them "on" the whale if possible. Soon there came a strangled roar, and hoarse triumphant shouts arose of "Stern all, he's in his flurry."

The exertions indulged in previously had so weakened the monarch that the death agony was feeble, and an exultant cheer went up as it became manifest that the great sea beast was dead.



A sensitive plant before and after having been breathed upon

SOME INTELLIGENT PLANTS

WE ARE accustomed to associate the idea of intelligence with such animals as have a somewhat highly developed brain, but it is an extremely difficult matter to lay down any line of distinction to indicate where intelligence first makes its appearance. Looking at the idea of intelligence in the widest possible manner, and understanding the doing of something for a particular end in view, we should be ready to admit that many of the processes going on in the leaves of plants can only be described as intelligent.

It was in that sense that Darwin compared the tip of the root to the brain of the lower animals. He said it was hardly an exaggeration to say that the tip of the root, thus endowed, "having the power of directing the movements of the adjoining parts, acts like the brain of one of the lower animals, the brain being seated within the anterior end of the body, receiving impressions from the sense-organs, and directing the several movements."

In this sense, plants have well-defined intelligence, which manifests itself in a thousand ways, particularly in the movements which their various parts display, either in search of food or for some other vital purpose. We shall study in detail some of the more striking of these movements.

WISDOM DISPLAYED BY ROOT TIPS

We may first notice the fact that the growth of a plant is not equal in all of its parts. Some portions exhibit a much more rapid growth than others, or grow during a longer period of time; and one of the results of this inequality of growth in different tissues is to produce movements in the various parts which are sometimes described as spontaneous. In both stems and roots the growth is usually more rapid on one side than on the other, and this results in the production of curvatures, or bends, unless the variation is such that the extra growth produced on one side is at once compensated for by a corresponding growth on the other. That is what actually happens at the tip of the root; and it has the result of making the root describe a spiral course through the soil, instead of a directly downward one. As a matter of fact, most stems in their upward growth also have a similar spiral movement, commonly in the opposite direction to the hands of a watch. The movement itself is termed "nutation."

If these spontaneous movements, of roots especially, be carefully studied, the observer cannot help being impressed with the idea that they have a very definite object in view. Hence the justification for the use of the expression "the intelligence of plants." Obviously the end and object of the movements is to attain that position in the soil which is best suited for the furnishing of the nourishment required. Seeds which lie under water sometimes send roots directly upwards. In all these cases the primary direction of the root-growth—the movement of the root-tip, that is—is extremely definite.

The directions taken by the secondary roots, however, from whichever part of the plant they may arise, are not so definitely circumscribed, though here, too, it is obvious that the movements are directed to reaching such positions as will give either security of attachment or moisture for nourishment. Study of all these movements shows that both those which take place in the aerial structures, and those which take place in the root, follow the same guiding principle, though the latter, of course, are made much more restricted, from the nature of their environment. If the root were to grow straight down, it would not come in contact with nearly so much material as it does by following a spiral course. This latter evidently offers the best means of encountering the most desirable food-supplies. This is part of what is meant by the intelligence of plants.

How a root seeks moisture

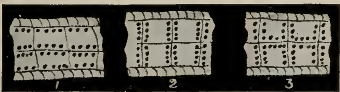
Further, one may readily observe that the growing portions of roots invariably turn aside from dry or barren soils in favor of a part in which there is more moisture and more nourishment. This movement towards the moisture is called "hydrotropism." In any considerable section of soil which has much vegetation growing at its surface, these movements of roots, in response to their environment, form an obvious and interesting study. One can see in any such cutting of ground a root turning away from dry, sandy, or inhospitable soil, until it comes to a richer deposit; and here, not having any necessity to turn further, it will grow now straight downwards, through good material. Arrived at the further boundary of this deposit, it will once more change its direction, and may even bend round and round, so as to keep in such a desirable neighborhood.

Changes in the color of leaves

Perhaps one of the most interesting of all the many examples of the intelligence of plants, in reference to the movements of their parts, is to be found in connection with the attitude and arrangements of their chlorophyll granules in relation to sunlight. These granules, it must be remembered, float freely within the protoplasm, which can move them to different places. This permits of their being either equally distributed throughout the cell, or aggregated together in clumps, or otherwise arranged. Perhaps the best example of these movements can be seen in plants like the liverworts, or in the mosses, where the green of the leaf is noticed to be lighter or darker, according to the intensity of the light which falls upon it. The same thing takes place in many flowering plants. The darker tint is observed when the light is weakest, whereas, under the action of the most intense, direct sunlight, the leaf appears yellowish. These alterations in color-appearance are due to actual movements of the chlorophyll granules, which take up different positions as the light varies.

A very simple experiment may be performed by anyone in this connection. If a piece of black paper be placed on a leaf which is exposed to the sun, in such a way as to cover up a part of the leaf, after a time it is observed, on removing the strip of paper, that the portion of leaf underneath is dark green, in comparison with that which was left exposed and unprotected. That is light green.

A reference to the diagram will explain this. We find that when the



THE MOVEMENT OF CHLOROPHYLL GRANULE IN A LEAF

This diagram of part of a section of a green leaf represents roughtly the change in the movements of the chlorophyll granules in response to the stimuius of (1) darkness, (2) direct sunlight, and (3) diffused light.

light is diffuse, the chlorophyll granules so arrange themselves as to cover those walls of the cells on which the light falls perpendicularly. This gives such portions of the leaf a dark-green appearance. When such a cell becomes exposed to direct sunlight, the granules leave these walls parallel to the upper surface of the leaf, and accumulate on those which are parallel to the direction of the light (2). The tissue, as the result, assumes a much paler color.

A word or two may be added in connection with leaves, concerning the movements of compound leaves, which exhibit interesting changes of attitude in places where they are exposed to considerable cooling during the night temperatures.

During the ordinary hours of sunshine such leaves are placed more or less parallel to the surface of the ground, with the upper surface open to the sky, and thus catching the direct rays of the sun. It is obvious that if the leaf were to remain in this attitude during the hours of the night, there would be great loss of heat, on account of radiation. The intelligence of the plant, as we have agreed to understand that term, here shows itself by the leaflets which compose the compound leaf folding themselves together either upwards or downwards, according to the species concerned, so that their broad aspect is placed vertically. In this manner there is much less loss from radiation than there would otherwise be.

Creeping and climbing plants

We may now turn our attention to an entirely different class of plant movement, namely, that which is associated with climbing plants, of which there are a large number whose stems are not sufficiently woody in texture to maintain a vertical or erect attitude. In a plant which has such a nature, one of two things may happen: the stem of the plant may continue to grow along the surface of the ground, bending or arching, as it does so, but coming in contact with the soil at intervals. Such plants have what are termed prostrate stems. On the other hand, however, there are a number of species which, in their efforts to reach the erect attitude, have developed various structures which enable them to grasp any neighborıng object that may afford a means of support, and to this object the plant attaches itself.

A good example is that of the hop, but in this case the whole plant participates in the movement, the entire stem twisting to the right.

The habits of sensitive plants

Next we may turn our attention to an entirely different aspect of what we have referred to as plant intelligence. There are movements which take place in plants during the hours of night, to which the name of "sleep movements" has been given; and it will be remembered that these consisted in the adoption of certain attitudes of the leaves or leaflets. A somewhat similar phenomenon is to be noted in connection with some plants that exhibit these sleep movements, and also in others that do not.

WILD CLEMATIS, OR VIRGIN'S BOWER

THE TWISTING STEM OF THE HOP

FLOWERS OF THE TRUE, OR ENGLISH, DAISY, CLOSED AT NIGHT BUT OPEN IN FULL DAYLIGHT

We refer to plants known by the general name of sensitive plants, from their different manifestations of this sensitive phenomenon. A number of the plants which assume the sleep position in the night exhibit a similar movement when they are either shaken or merely lightly touched, and, as a matter of fact, they appear to be even more sensitive to this disturbance than to darkness. The onset of a very slight breeze of air may be sufficient to cause the leaflets to fold up.

Although this curious change occurs in some of the same plants that adopt the sleep position at night, it is not to be therefore inferred that the two things are the same. The attitude of the leaf is determined by the condition of a little cushion of tissue, called the *pulvinus*. This cushion remains quite rigid in the sleep position, while on the other hand, it undergoes a very remarkable change in the movements produced by shaking the plant. It becomes less turgid, by discharging some of its water into another part, and the result of this is to cause a bending of the leaflet.

Under natural conditions practically the only two things which stimulate the protoplasm to act in this way are the action of the wind, and still more emphatically, perhaps, the irritation caused by the falling of drops of rain on to the leaf. In the Indian plant already referred to, most remarkable movements immediately follow a shower of rain. The leaves which first come in contact with the drops fold together downwards, but not only do these leaves do so, but actually, also, those in closest proximity to them, even though no actual drops fall thereon. Well might such a plant be termed "sensitive." Even the leaf-stalk, which bears the mass of leaves, bends in the direction of the earth; and the practical consequence of these movements is that the drops of rainwater flow over the bent stalk, and over the hanging leaves, so that all the moisture is immediately drained off, and none remains upon the surface. No better example can be imagined illustrative of plant intelligence, or movements directed by some principle towards the attainment of a definite purpose.

Why the Leaves Fold Up

Very similar processes are seen in the leaves of the sundew, and in those of Venus's fly-trap, as well as in some of the mimosas. The actual movements are not identical in all these cases, but they are produced by the same sort of influences, and for precisely analogous purposes. The freeing of the plant from raindrops, however, though obviously one of the objects in these movements, is not the only one. This may be concluded from the fact that quite other conditions than rain produce the same movements, particularly such factors as hot, dry winds, impregnated with particles of dust or sand. Here it is obviously to prevent excessive transpiration that the leaves fold together. So we may safely conclude that several different advantages accrue to the plant in virtue of the powers of movement we have been describing. At night the loss of heat by radiation is minimized. In the heat of the day extreme transpiration is kept in check. In wet weather, injury to the leaves, or possibly to the whole plant, which might collapse under the weight of accumulated water, is prevented.

The Bursting Open of Flowers

A movement which may be observed in almost all flowering plants is that which takes place at the onset of daylight, or at some varying period during the day afterwards. This is the opening of the passage to the interior of the flower. Very detailed observations have been made on the times at which this separation of the petals takes place, and the following examples, quoted by Kerner, may be noted here.

In the case of the honey-suckle, the whole series of movements in the process begins by the lowest lobe of the corolla folding back, this being followed by the same thing in the other lobes, which liberates the stamens, and they spread out like fingers. This series of movements takes about two minutes. The evening primrose is still more rapid in its opening, the petals springing apart, and being wide open in half a minute. This may truly be described as the bursting open of the flower. In some cases this opening occurs quite quickly enough to be followed with the naked eye, and in one or two instances is accompanied by a slight noise.

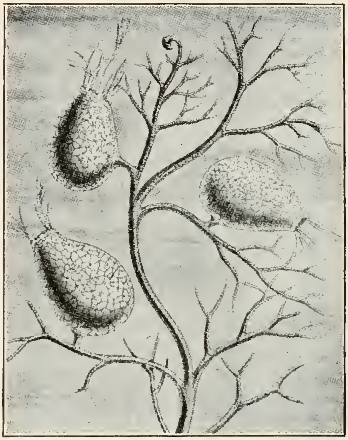
Hours when flowers open their lips

With regard to the times during the day when these opening movements may be noted, Kerner gives the following instances: "There are flowers which open so early in the morning that they greet the first rays of the rising sun with fully expanded corollas. That common garden climber, Morning Glory, opens its buds at four a. m. Wild roses also open between four and five a. m. Between five and six many species of flax open. Between six and seven, willow-herbs; between seven and eight, bindweed. Between eight and nine, many gentians, and wood-sorrels. Between nine and ten, most tulips open; between ten and eleven, the centaury and chaffweed

"From noon till evening comes a long interval. No plant is known in our latitude which, under ordinary circumstances, opens during the afternoon. Towards sunset, however, it recommences. About six p. m. the honeysuckle opens, shortly followed by the evening primrose. Between nine and ten, the Queen of the Night, the Mexican cactus, opens."

Weapons of insectivorous plants

When we come to consider the subject of plant defences we shall have to make reference to poisonous and insectivorous plants. One or two of these, however, must be noted here from the point of view of their movements. We may take those to which we have already referred. The whole of the genus sundew are excellent examples of plants whose movements are directed to the capturing of small insects. The plants themselves are common enough, and especially prevalent on damp soil and marsh land. There are some forty species of sundew, all of which show as their most conspicuous character a slender red filament, that is club-shaped at its free end, and carries a refractile globlet of fluid. These filaments project from the upper surface of the leaf, the under aspect of which is smooth, and very often rests upon the damp ground. The filaments have been compared in their appearance to pins stuck in a cushion. They are various sizes, the shortest being in the middle of the leaf, the longest at the outer edge, and each leaf carries about two hundred of these little filaments. The club-shaped swelling at the end is in reality a gland, which secretes a clear globlet, that looks very like a drop of dew, but is really a sticky, viscous substance.

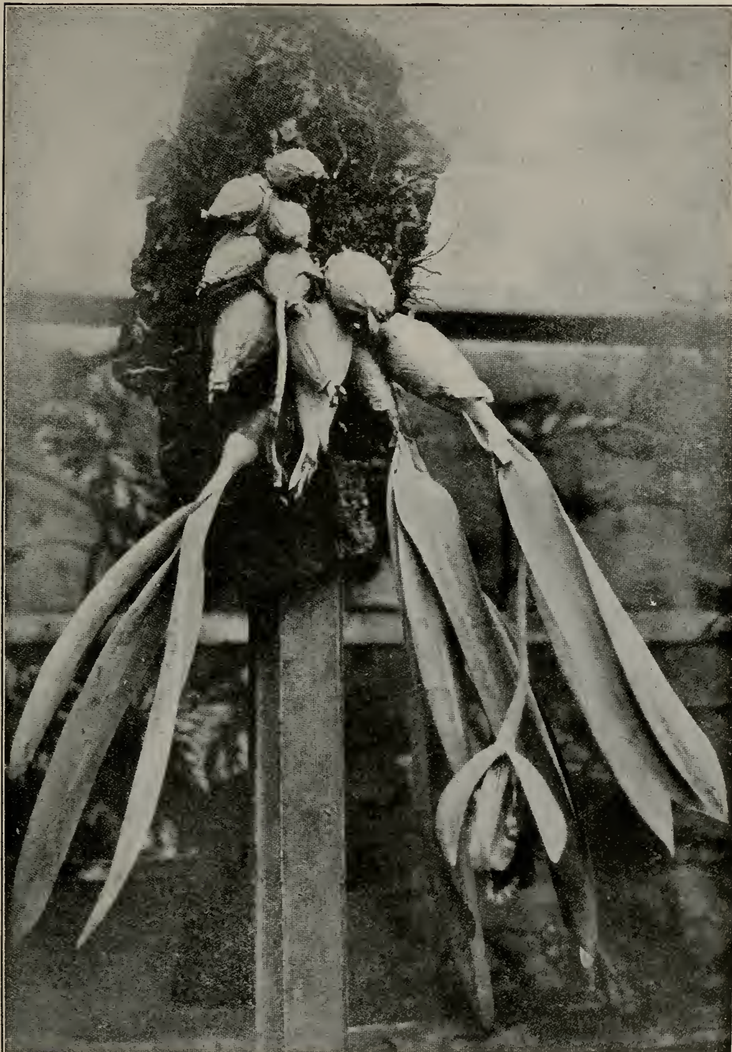


THE TRAPS OF THE BLADDERWORT THAT CAPTURE TINY AQUATIC ANIMALS

Discriminative intelligence of sundew

A wonderful example of plant intelligence is to be found here. The movements we have mentioned above in connection with wind and rain and dust are utterly ignored by the sundew. Experimentally, one may irritate these filaments with minute particles of ordinary foodstuffs, such as sugar, or with solid particles of sand, and so forth, and the only result is to increase the secretion of the

A PLANT THAT BREAKS THE RULES



This orchid from Mexico, reverses nearly all the normal conditions that govern plant growth. It flourishes on a piece of dry bark, with its roots in the air, instead of in the soil. The atmosphere provides it with sufficient moisture, combined with that stored in its bulbs. It grows upside down, with its leaves towards the ground.

gland, which assumes an acid reaction. The leaf itself does not move, nor does there follow any attempt at digestion.

Let a small insect, however, in its search for honey, impinge upon the leaf and touch the gland, and—wonderful to relate—the composition of the secretion is at once changed, in so far as it becomes a digestive ferment, the object of which is, of course, to appropriate the unfortunate insect as food. Remarkable movements take place in the filaments, or tentacles, and they close in, so to speak, as the tips of the fingers would do if bent towards the palm of the hand.

Gradually all the filaments bend over towards the insect which has been caught in the sticky, glandular secretion, and in a time varying from one to three hours all of them are found bending upon it. No matter where the insect may alight, the tentacles move down upon it exactly to the right spot, whether it be in the center or otherwise. Should there be two insects for the same leaf, at the same time, in different parts, then some tentacles will converge on the one, and some on the other.

Digestion of insects by sundew

The result of the whole process is that the captured little creature is covered with secretion and digested. The whole process of absorption is complete in a couple of days. What is left behind is carried away by the wind when the tentacles reassume their original attitude. Small midges are the usual victims of the sundews, but flies, and ants, and beetles also suffer a similar fate. As many as thirteen different species of captured animals have been found on a single leaf at the same time.

The really interesting fact about these wonderful, intelligent movements is not merely that they contribute to the nutrition of the plant, but that the movements take place in tissues other than those which are actually the first to be stimulated by the insect. In other words, there is a transmission, or carrying, of the original impulse from cell to cell through many cells at a speed which can be actually measured.

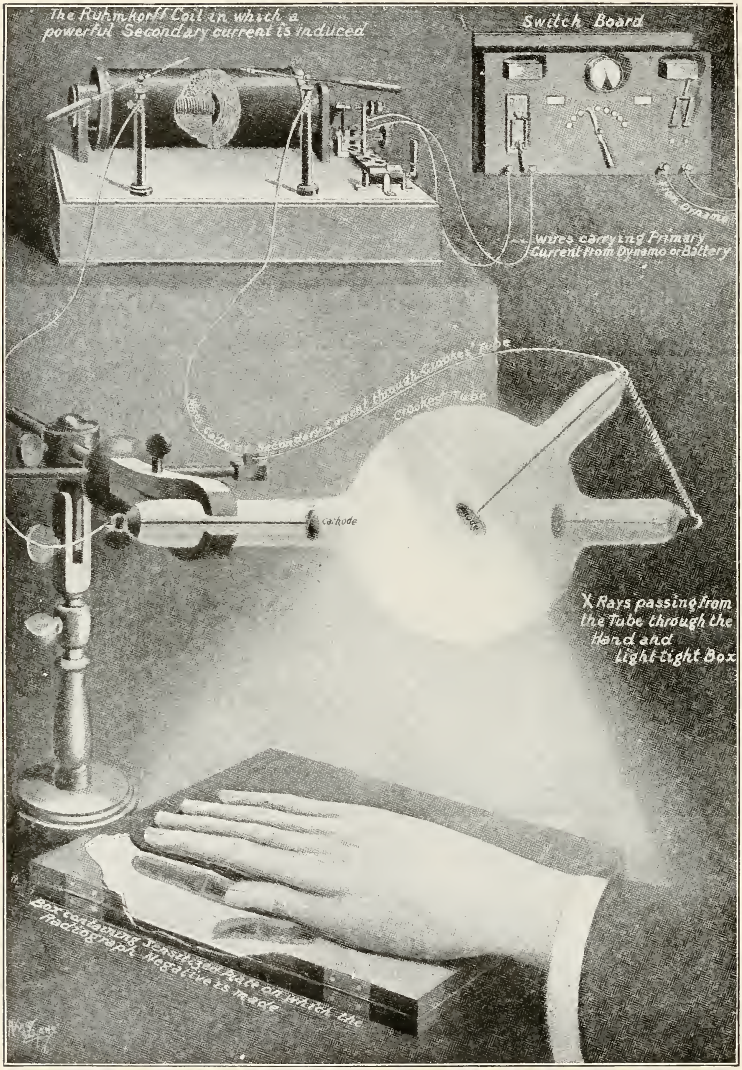
This suggests at once to the mind an analogy to the transmission of a nerve impulse from the brain to a distant muscle in the arm or leg. How sensitive the leaves of the sundew are may be imagined when it is stated that "a particle of a woman's hair, 0.2 mm. long, and weighing 0.000822 mg., when placed upon a gland of round-leaved sundew, caused a movement of the tentacle belonging to the excited gland."

A similar experiment on the human tongue would fail to give any indication of the presence of the hair, though the tip of the tongue is very sensitive.

Marvels of Modern Mechanism

ROENTGEN OR X-RAYS
THE MASTER ENERGY OF RADIUM
MOVING PICTURES—THE WORLD IN REVIEW
MEASUREMENTS OF TIME
TELEGRAPHY—MESSAGES BY LAND, SEA AND AIR
MODERN WAR'S MAILED HAND—GUNS AND SHELLS
FUTURE SOURCES OF POWER

RADIOGRAPH OF THE STRUCTURE OF THE HAND



This picture explains the mechanism by which X-rays are produced in a Crooke's tube for the purpose of radiographing a hand placed on a box containing a sensitized plate.

THE X-RAY—MAGIC TUBE OF MODERN SCIENCE

"IF THE discharge of a fairly large induction-coil be made to pass through a Hittorf vacuum-tube, or through a Lenard tube, a Crooke's tube, or other similar apparatus which has been sufficiently exhausted, the tube being covered with thin, black cardboard, which fits it with tolerable closeness, and if the whole apparatus be placed in a completely darkened room, there is observed at each discharge a bright illumination on the paper screen covered with barium platino-cyanide, placed in the vicinity of the induction-coil, the fluorescence thus produced being entirely independent of the fact whether the coated or the plain surface is turned toward the discharge tube." With these words, Professor W. K. Roentgen, in December, 1895, announced to the world one of the most profound discoveries of the nineteenth century, a discovery that for far-reaching results must rank, indeed, as one of the greatest events of all times.

Figure 1. William Konrad Roentgen, the discoverer of the X- or Roentgen rays.

How the discovery was made

Roentgen's discovery was the culmination of a long series of experiments with the vacuum tube. So long ago as the eighteenth century, the Abbé Nollet arranged an electrical apparatus in such a manner as to send a spark through a glass globe which he gradually emptied of air. Experiments continued on into the next century, but it was not until 1859 that noteworthy results were obtained. In this year Plucker succeeded in obtaining a far higher vacuum than any heretofore known, and produced with it another "curious" phenomenon—a greenish phosphorescence that lined the walls of the tube—attributed to the action of cathode rays.

Cathode Rays explained

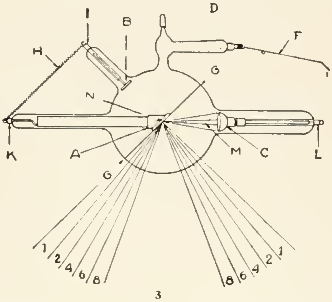
The "cathode," the reader will bear in mind, is nothing more nor less than the negative pole (see c, figure 3), or the point at which the electric current leaves the tube; the positive pole, or the point at which the current enters the tube, being called the "anode." This deduction of Plucker's forms, really, the starting point of the observations that led up to the discovery of the x-ray itself, as also the further fact that the "cathode" rays respond readily to a magnet placed outside the tube, changing their direction as the position of the magnet was changed.

In 1879, Professor Crookes (now Sir William), with a remarkably high vacuum, obtained powerful rays which he directed against a sort of windmill, or vane, placed within the tube, the vane revolving under the impact of the rays. This and other experiments led Crookes to announce the theory that the cathode ray was a stream of infinitesimally minute particles of matter charged with negative electricity.

Roentgen's Laboratory Gives Up Its Secret

A year later Professor Wilhelm Konrad Roentgen, Professor of Physics at Würzburg University, was one day making experiments in his laboratory

DESCRIPTIVE X-RAY TUBE



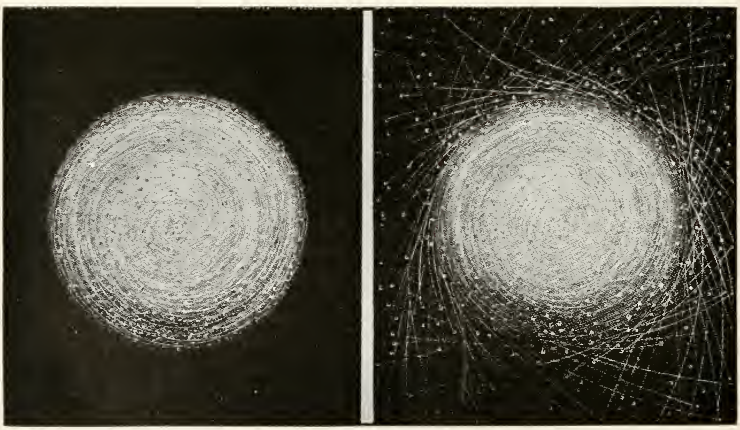
A—Anode
B—Assistant Anode
C—Cathode
D—Regulating Chamber
F—Regulating Adjuster
G—Hemisphere
H—Connection Wire
I—Assistant Anode Cap
K—Anode Cap
L—Cathode Cap
M—Cathode Stream
N—Focal Point

with the vacuum tube. Beside the tube lay a small quantity of crystals of barium platino-cyanide, placed there quite by accident. Happening to glance down at the screen, he observed that under some influence exerted by the tube, they were aglow with phosphorescence. To ascertain whether the phosphorescence could be due to the cathode rays, he covered both the tube and the screen, and lo! not only the phosphorescence continued, but dark shadows were cast on the screen by the hand and other objects placed between the tube and the screen. Thus was discovered, quite by accident, a new ray, which because nothing whatever was known of it, and x being the symbol of unknownness, was called by Professor Roentgen the "x-ray."

Wild was the excitement that prevailed throughout the scientific world, and many and ingenious were the theories that arose to account for the new phenomenon.

The Mystery of Matter

Later experiments by Sir J. J. Thomson, conducted in the Cavendish Laboratory at Cambridge, showed that the powerful electric discharge as it passed through the tube not only broke up into atoms the molecules of matter which happened to be in the tube, but



The theoretical difference between an atom of ordinary matter and an atom of radio-active matter further separated them into the infinitely minute particles of negative electricity known as electrons —now recognized as the unit of matter.

The cathode ray Thomson found to be merely a stream, or beam of these electrons shooting out from the cathode at the inconceivable speed of 60,000 miles a second, a third that of light. The fact that these rays can be bent or deflected at will, whereas the Roentgen-ray resists every attempt to alter its course, penetrating with the utmost readiness the densest materials, showed it to be different from the cathode rays. The further fact that the Roentgen-ray cannot be refracted, diffracted, or polarized, showed that the Roentgen-ray is not, as many supposed, identical with ordinary light, although in certain respects it is akin to light.

These and later experiments by Thomson and by Sir George Stokes, of Cambridge University, demonstrated the propagation of Roentgen-rays by showing that the stream of cathode rays by impinging upon a hard substance, as against the wall of vacuum, was converted into an electrical pulse of irregular length and rhythm. The manner of this may be observed from the preceding illustration which shows the main features of the Roentgen-ray tube as employed today.

Professor Bragg has lately worked out the most fascinating idea of the nature of the marvelous x-ray.

He supposes that when the stream of negative electrons of the cathode ray strikes against the platinum point in the modern glass x-ray tube, it breaks up some atoms of platinum, and robs them of some of their positive electrons. Thus is fashioned a stream of doubled-natured bodies, consisting of the original negative electrons, to each of which is attached a small charge of positive electricity. And this is the x-ray. Being neither positive nor wholly negative, it does not answer to an electro-magnet. And, moreover, it is not impeded by the electrical attractions of the atoms through which it passes on its shining march through matter. We must remember that an atom consists of an empty space—somewhat like our solar system on a very small scale—in which a few infinitesimal negative electrons are spinning round a large positive electron. There is therefore at times ample room for the x-ray to pass through atom after atom, throwing on the screen only a faint shadow of the substances through which it swiftly travels.

Yet, sooner or later, there is a collision. One of the results is that the x-ray is robbed of its stolen property—its positive electrical charge—and reduced to its original character of a cathode ray. The same thing happens with the x-ray that proceeds from radium. As its speed slows down, just before its work is done, it becomes a cathode ray of negative electrons, with a diminishing energy of velocity; and at last its particles penetrate into an atom from which they have no longer the power to emerge. And that is practically the end of it. It is absorbed in the existing and permanent structure of the universe—in the gases of the air or in the atoms of the walls, ceiling, or floor of the room in which the x-ray apparatus is being used.

From a medical point of view, when the x-ray comes to an end in human flesh and is re-transformed into the original cathode ray that produced it, it often may have a serious effect upon the flesh of the x-ray operator. It breaks up the cells of that part of the human body on which it has been constantly falling. The consequence is that dreadful sores are sometimes formed upon the hands of an operator who is continually exposed to the x-rays. Even the constant study of the action of x-rays by means of a fluorescent screen hurts the eyes of an operator, causing an inflammation of the outer portion of the eyeball. The fact is, the x-ray is so intense a form of energy that it gives rise to what are called secondary radiations. It breaks bits off the atom against which it strikes continually; and when these atoms are the elements of substances in the living flesh of the x-ray operator the result is at times serious.

Several brave men who worked the x-rays in hospitals, with great benefit to thousands of injured patients, have now lost their fingers, hands, or arms through the strange, spreading, and terrible sores produced by continual daily exposure to the extraordinary power of the x-rays.

Yet it must not be thought that a patient nowadays is in any danger when the x-ray is used upon him by a skilled operator to find some broken bone, or some diseased organ, or some foreign body, such as a needle or bullet that has got embedded in his flesh. If a very long exposure of some hours is necessary, his skin may feel a little sore, but the soreness will pass away. It is only the heroic operator, day after day exposing himself to the weird force of the ray, who is in peril of great and permanent injury. In an ordinary way the action of the ray on human flesh is said to be often beneficial. There is, for instance, an ulcerous disease of the skin produced by the same tubercle microbe that causes consumption of the lungs. A careful application of the rays brings about an inflammatory reaction, which causes the tubercles to become visible. This is followed by a loosening of the tubercles; they are then sloughed off in masses, and a healthy scar tissue grows underneath.

A similar beneficial result is often produced by means of the Finsen light, but the x-rays are quicker in action, and less expensive in use, and they can be applied to cavities which are inaccessible to the Finsen light. Several other skin diseases and various kinds of malignant growths have been cured by treating the sufferers with x-rays. Some cases of cancer of the throat and breast are reported to have been cured by applications of the rays, lasting for ten minutes, and repeated daily for some weeks. But on the whole it seems that the new treatment is only likely to be successful in diseases affecting the outer parts of the body that can be directly subjected to the action of the rays. When the malady is deep-seated, the healthy surrounding portion of the body tends to become seriously inflamed by the rays as they pass through on their way to the seat of the disease.

At the present time there are several means of protecting an operator from the action of the rays. In some cases, he needs only to use a very mild form of the new power. This is obtained by allowing a certain amount of gas to enter the glass tube, and so lower the vacuum. The ray then produced is very soft; it cannot penetrate far. Hard rays, on the other hand, are produced by increasing the vacuum and making the air in it more rarefied. When this is done, the operator has to be careful to protect himself.

There are two principal methods of protection. In one, advantage is taken of the fact that the x-ray cannot penetrate lead. So a lead-glass is placed over the vacuum tube, leaving only a small point in the inner soda-glass

APPARATUS BY WHICH X-RAY PENETRATES THE BODY

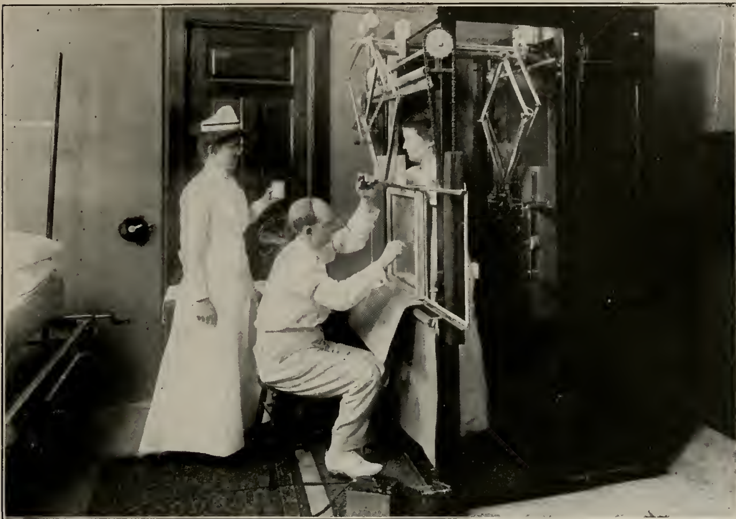


Figure A. Instrument for doing fluoroscopic observations with the patient standing. This particular cut illustrates the observation of the stomach following the bismuth meal. The nurse is handing the patient a glass of buttermilk into which has been stirred an ounce of bismuth powder. This bismuth meal is opaque to the ray and permits the study of the outline of the stomach. In this same instrument one may study the heart, the lungs, the diaphragm, the stomach and the intestine. The tube is enclosed in a lead-lined box behind the patient, the rays passing through the patient and casting a shadow upon the fluorescent screen immediately in front of the observer

Figure B. A horizontal fluoroscopic apparatus upon which the patient reclines during fluoroscopic observation. A screen is laid over the patient, while the tube is underneath the table upon which the patient is lying vessel through which the x-rays stream on to the patient. Again, the operator now has various devices for testing the strength of the rays, without putting his own hand between the stream of invisible force and the screen, in order to measure the penetrative power. This rough-and-ready manner of testing the rays was the chief cause of the loss of fingers, hands, and arms by the band of brave men who first worked the rays.

The modern operator measures the power of the radiance he is about to apply to a patient, by means of curious and delicate instruments that show the amount of electricity the invisible ray is communicating to the air outside the tube. The degree of electrification exactly denotes the softness or hardness of the unseen radiance; and a careful operator never now exposes his eyes or his hands to the action of the unseen force. During his work he uses rubber gloves, and puts on a pair of lead-glass spectacles, and wears a rubber apron.

His work has, moreover, been greatly lightened by the progress made in x-ray photography. In a general way, the invisible radiance that penetrates through flesh and bone is employed for finding out what is the matter with the patient. This can be done much quicker by means of photographs of the interior of the human body than by studying the actual picture thrown on the fluorescent screen. For the photographs can be minutely examined in broad daylight and at leisure, and compared with similar photographs of the flesh and bones and organs of healthy people. For this reason x-ray photography has become, both for the surgeon and the physician, the most important by far of the medical applications of the new force; and inventors are still busy in perfecting this branch of radiography.

At first there were obtainable only flat silhouettes of the shadows cast by the x-rays as they traveled through the human body. By using just a medium hard ray, which did not penetrate through the bones, the skeleton of the human frame could be shown in dark shadows amid the lighter, vaguer tints of the flesh. The method was useful in discovering fractures of bones and foreign bodies of metals, such as bullets and splinters of shell in wounded soldiers, and needles and nails and other metallic objects due to domestic and industrial accidents. It was early shadow-photographs of this sort that directed the general attention to the wonderful properties of the x-rays in the first years following their discovery.

But the trouble with a flat shadow-photograph was that it gave no indication of depth. It only showed in outline the internal structure of the human body. In the case of fractures of bones, this difficulty was overcome to some extent by taking several photographs—from the sides as well as from the back and front of the injured limb or other bony part. So the surgeon was fairly well contented with a series of flat silhouettes that the x-rays gave him.

It was some time, however, before the new invisible force, that can penetrate wood and steel, was of much use to the physician. In many cases he required a clear and perspective view of the flesh organs and of the softest parts of the tissues. And this is what he has now obtained. By using soft rays on certain parts of the body, and taking two separate photographs, and combining them for examination in a stereoscope, he can often get a perspective vision into the human body. Everything stands out in order in soft relief, so that various diseases of the lungs and heart and

A SERIES OF X-RAY PICTURES OR ROENTGENOGRAMS

Figure C. The human vermiform appendix as it appears when filled with bismuth

Figure D. The foot enclosed in the shoe

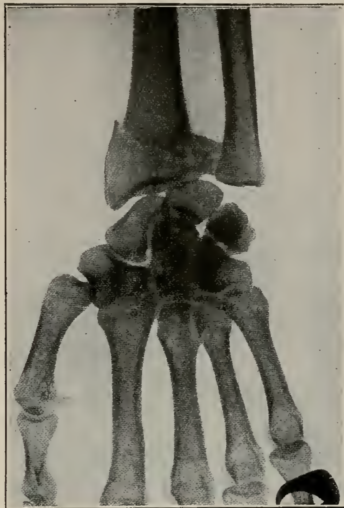


Figure E. The bones of the arm

Figure F. Skeleton of a squirrel

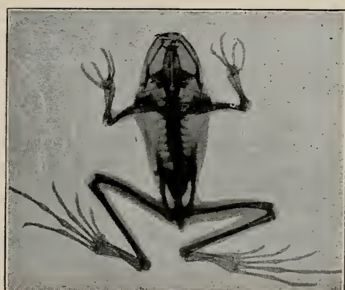


Figure G. Skeleton of a frog

other organs can be traced. And there is another more technical method, called plastic x-ray photography, which gives similarly excellent results. All this is a magnificent advance in the art of locating the effects of a malady and observing exactly the results of a curative treatment. The physician can see with his own eyes the improvement that is taking place, or the need there is to adopt some other form of cure.

Moreover, he can give the patient certain bismuth preparations that will coat some of the interior parts of the body, and make them stand out very vividly in a stereo x-ray photograph or a plastic x-ray photograph.

Just recently, an extraordinary application of the medical use of x-rays has been made by converting the human body into a fluorescent screen. It has long been known that a natural fluorescence existed in certain human tissues, and that the nerves, muscles, and brain, and the chief organs, contain a fluorescent material that resembles quinine.

Now experiments are being made in dosing patients with quinine preparations, and then making the medicine shine in the body by applying x-rays to the part that is diseased. Some good results are reported to have been obtained in certain tuberculous maladies. It is too early yet to give a reliable decision on the general value of the method.

Indeed, much yet remains to be done before the various forms of x-ray treatment and examination are perfected. At present tumors of soft tissues are photographed with great difficulty, owing to the surrounding structure having nearly the same density. Diseases of the brain are especially hard to trace by means of the x-ray. For the shadows of the bony vault of the head greatly obscure the details of the soft structure. And, moreover, as the rays pass through the skull, they produce cathode rays that tend still further to confuse the shadowy image of the brain. Yet, a blood-clot in the brain has been revealed by the wonderful ray. So we may expect the intricate technique of the modern operator to be at last developed to a point at which the entire internal parts of the bodies of suffering mankind will be made clearly visible to the modern physician.

What has already been accomplished is so wonderfully useful that it is revolutionizing medical science. In course of time every surgeon and doctor will be an expert x-ray operator. He will begin by studying the healthy functions of the body with a fluorescent screen and the x-ray stereoscope. Then he will go on to learn all the signs of hidden diseases that the x-ray reveals. So, when he is fully trained, he will be able to tell, almost at a glance, what is wrong with his patient. In the meantime, the new scientific blood-tests, by which the cause of a disease is revealed under a microscope, will be extended and in many cases simplified.

So there ought to be in the future no occasion for a careful medical man to make any mistake in his diagnosis of an illness. The healing art, that still remains an art, will then be transformed into a science; and this science will grow more exact as man obtains a larger control over the microbes of disease.

It is more than evident that the x-ray will be found permanently useful in its marvelous revelation of the interior structure of the human body. No one should submit to the action of the x-ray, whether for treatment or for examination, except at the hands of a skilled operator.

THE MASTER ENERGY OF RADIUM

FREQUENTLY in science one great discovery leads to another. This was the case with this strange and wonderful substance known as radium. In the year 1896 Professor Roentgen discovered the very useful rays which bear his name and which are often called x-rays. The discovery of radium may be directly traced to the discovery of x-rays. And this is the way it happened.

DISCOVERY OF RADIUM DUE TO DISCOVERY OF X-RAYS

We know that x-rays are produced by sending an electric current through a glass tube from which nearly all the air has been removed. When the x-rays are being generated certain parts of the walls of the tube are seen to glow with a beautiful yellowish-green color. It was thought by those who first studied the x-rays that this fluorescence of the glass might in some way be inseparably connected with the emission of the x-rays and that possibly phosphorescent substances such as zinc sulphide might give rise to x-rays. The chemical known as zinc sulphide is a white powder. If this substance is exposed to sunlight for a few minutes and then removed to a darkened room it is found to glow or phosphoresce with a beautiful pale blue light. Other substances also behave in a similar way.

EXPERIMENTS OF BECQUEREL

M. Henri Becquerel examined a number of these phosphorescent compounds by testing their effect upon a photographic plate. It was known that x-rays will pass through many bodies which are opaque to ordinary light and make an impression on a photographic plate. Becquerel exposed a number of phosphorescent substances to sunlight and then placed them near a photographic plate that had been wrapped in black paper. It was found that the plate had been affected as if struck by light. He next tried an experiment to determine whether the preliminary exposure to sunlight was necessary in order to secure an impression on the plate. It was found that the photographic plate was blackened even when the phosphorescent substance had not been previously subjected to sunlight. Pushing his experiments still further Becquerel found that he could obtain the effect with substances that *did not* phosphoresce. In one experiment he placed a coin between the substance being examined and the photographic plate and upon developing the plate he found a shadow image of the piece of metal. In developing that photographic plate Becquerel unlocked a door which had long hidden many of nature's most precious secrets. In that dark room that day man took a long step forward in his search for knowledge. Here was a substance capable of spontaneously emitting something which passed through material opaque to ordinary light. Becquerel had discovered a new form of radiation, and these new rays are called Becquerel rays in honor of their discoverer.

MADAME CURIE'S INVESTIGATIONS

The substances used by M. Becquerel in these experiments were compounds of the element uranium. Inspired by the important discovery of the Becquerel rays other investigators at once began a search to determine whether any other substances possessed this peculiar property. In a short time two investigators, Schmidt and Madame Curie, independently discovered that compounds of the element thorium emitted rays which were similar to those given out by uranium. Those compounds which were found to give out these strange rays came to be known as *radio-active substances*, and this new property as *radio-activity*.

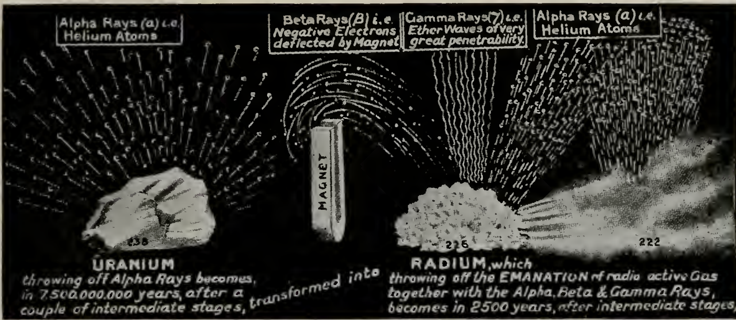
How to demonstrate radio-activity

It is not difficult to repeat some of those early experiments in radio-activity. An ordinary gas mantle contains a small quantity of thorium. Wrap a photographic plate in black paper and place the same, film side up, where it will not be disturbed. On top of the plate and outside of the light-proof envelope place a gas mantle. The mantle should be broken open so that it will lie flat. After about ten days develop the plate in the usual manner and a distinct image of the gas mantle will be found on the plate. The Becquerel rays will have penetrated the paper and produced an impression on the sensitive photographic film. If a piece of metal such as a coin be placed between the mantle and the paper it will be found that the rays have been stopped by the metal, thus leaving its shadow on the plate. The accompanying radiographs were made by the author in a manner similar to the process just outlined.

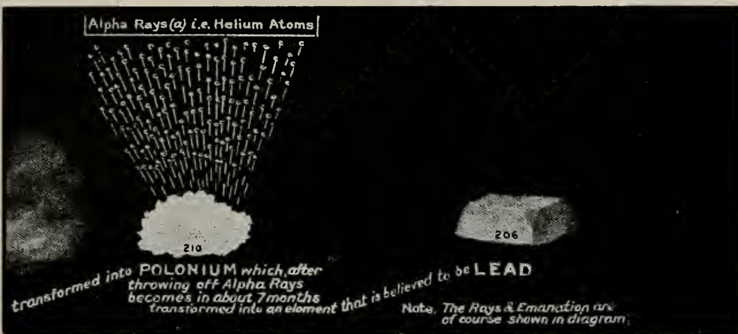
The Ores producing radio-active elements

But this strange and fascinating story of discovery does not stop here. Having found two radio-active elements it was but natural to examine the mineral ores from which these elements are obtained. Now it will be remembered that an ore usually contains a number of different elements in the form of a compound or a mixture of compounds. It happens that the radio-active element uranium is found in the ore known as pitchblende. This ore contains lead, oxygen and nitrogen as well as uranium. Hence if we have an ounce of pitchblende only a small part of this amount will be pure uranium. M. and Ma-

A FILTER-PRESS FOR EXTRACTING URANIUM SALTS, THE MOST IMPORTANT RADIUM-HOLDING MATERIALS



PRODUCTION OF RADIUM FROM URANIUM, AND OF POLONIUM FROM RADIUM



THIS PICTURE SHOWS HOW THE CHIEF RADIO-ACTIVE SUBSTANCES DISINTEGRATE

dame Curie compared the radio-activity of equal amount of the element uranium and the ore pitchblende and found to their astonishment that the ore was much more radio-active than the metal uranium itself. This at once lead them to the important conclusion that there must be some other substance in the pitchblende which was many times more active than uranium itself.

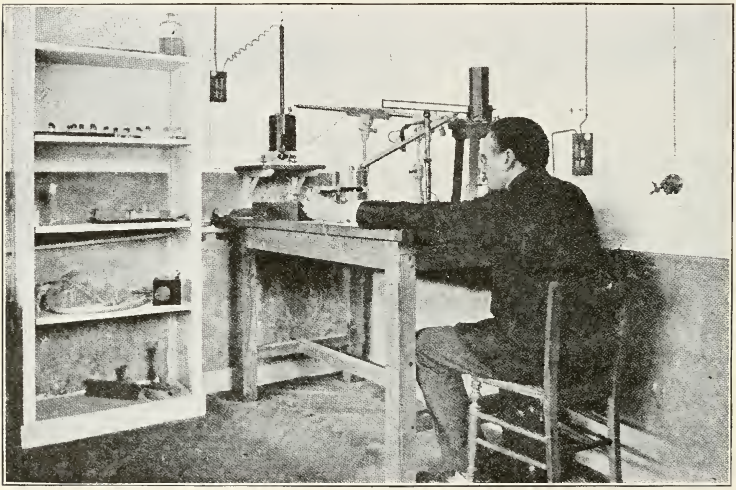
The Curies at once began a search for this unknown substance. By an extremely long and very tedious chemical process these tireless investigators were able to separate out an exceedingly small amount of this substance after working over several tons of pitchblende ore. In fact, *two* radio-active elements were discovered and separated from the ore, to one Madame Curie gave the name *polonium*, naming it after her native country, Poland, and the other was called *radium*. Both of the elements were hundreds of times more radio-active than uranium. And so we see how, beginning with a search for new methods of producing x-rays, we are led to the discovery of at least two new elements—elements which possess properties entirely unlike those of any known heretofore—elements which have proved vastly important because of what they have taught man about the nature of matter.

How radium differs from other elements

But before we consider the question of the interpretation of radium let us glance for a moment at some of the more striking properties of this element, in order that we see in what respect it differs from other elements such as gold or silver or carbon.

One of the several striking and interesting properties which distinguishes radium from other elements is that it is self-luminous. While the self-luminosity is not intense enough to be seen in ordinary daylight it can be seen by artificial light. This light which radium emits comes from the entire mass of the substance and not simply from the surface, and continues to be given out for long periods of time. Samples of radium which have been under observation for years are still self-luminous. Radium is the only known substance that possesses the peculiar property of self-luminosity.

Another strange fact about radium is that it produces heat spontaneously, or, in other words, it warms itself. The fact was discovered by M. Curie and Laborde that salts of radium have a temperature that is always higher than that of their surroundings. This shows that heat is produced *in* and *by* a radium compound itself. And a still further astonishing fact is that the quantity of heat developed by the radium is comparatively very great. It has been determined that a piece of radium gives out enough heat every hour to melt its own weight of ice, and that it will continue to give out heat at this rate for an indefinite period of time—in fact as long as the radium, as such, exists.



MEASURING THE RADIO-ACTIVITY OF SALTS CONTAINING RADIUM, AS THEY ARE MORE AND MORE PURIFIED

Radium, which has not yet been separated pure, but in its most potent form as a chemical compound is worth more than $2,000,000 an ounce, is found in infinitesimal quantities in combination with other substances. Thus a ton of pitchblende residues, when treated for 2½ months with five tons of chemicals, and washed with fifty tons of rinsing water, will produce from two to four pounds of radium bromide of low radio-activity. This salt, under successive purifications and crystallizations, leaves smaller amounts of radium with a higher radio-activity, until only one-thirtieth to one-sixtieth part of a grain of radium remains from a ton of residue; but its radio-activity will be forty thousand times greater than that of the larger mass of radium bromide first obtained.

Still another striking property of radium is its ability to excite phosphorescence in various substances. Such substances as paper, cotton, diamond, ruby, various chemical compounds, and certain kinds of glass become luminous when brought near a sample of radium. In this connection it is of interest to note that glass which phosphoresces in the presence of radium slowly changes to a violet color when exposed to the influence of radium.

COMMON AIR FAIRLY GOOD CONDUCTOR

It is also true that common air, which, under ordinary circumstances, does not easily conduct electricity, becomes a fairly good conductor when exposed to the action of radium. So marked is this effect that it is impossible to keep a body charged electrically within several feet of a sample of radium. This property of radium serves as a very delicate test of its presence. A quantity so small that it cannot be seen with the highest power microscope or even detected by the spectroscope can be quickly and easily identified by its effect in discharging an electrified body. The Curies used this method to detect the presence of, and to measure the radioactivity of specimens of radium which they extracted from pitchblende.

The chemical action of radium in producing effects similar to that of light upon a photographic plate have already been referred to. Closely allied to this property is the effect produced by the radiations from radium on animal tissues. It is known that an active sample of radium will produce severe burns when kept near the skin for any length of time. Such wounds are both painful and slow to heal. Because of this fact specimens of radium which are strongly radioactive and which are to be carried about are kept in lead capsules. Experiments are being carried out at the present time to determine whether the radiations from radium will affect certain diseased tissues of the human body in such a way as to bring about a cure, but the results of these experiments have yet to be learned.

The properties of radium which have been briefly described above serve to distinguish this element from any other known substance. In fact, certain of its characteristics are so entirely different from any phenomena known to man that radium stands in a distinct class by itself. Is it possible to account for the strange behavior of this unusual element, and what does radium teach us about the nature of matter and the sources of the world's supply of energy? These are some of the questions which will now claim our attention.

EXTRACTION OF RADIUM FROM ORES

The extraction of radium from the ore is exceedingly difficult and expensive, and involves three processes, mechanical preparation, chemical treatment, and "fractionization," as described by Wickham and Degrais, eminent French scientists, as follows:

Mechanical Preparation: This consists of a series of different operations: grinding, which crushes the pieces of ore to the size of a nut; pulverization, which reduces it to a very fine powder; and, finally, mechanical enrichment by dressing.

Chemical Treatment: Radium is found in an insoluble state in the residues of pitchblende, unassailable by acids, mixed or combined with earthly silicates, alkaline earth and alkalis, etc., all being inactive substances. Repeated washing with hydrochloric acid and water rids the residue of a large quantity of this inactive matter. The insoluble part contains the radium. It is then submitted to a long boiling with carbonate of soda, transforming the radium salts into salts which are still insoluble but henceforth able to be acted upon by acids. Hydrochloric acid is again used to dissolve out the radium and permit of its concentration.

Fractionization: This operation is extremely delicate. It is divided into three phases: gross fractionization, fine fractionization, and the definite fractionization of the bromides.

In crystallizing a solution of radium-bearing barium chloride, it is found that the crystals contain more radium than the mother liquor which held them. It is this fact which is utilized in fractionization to determine a series of crystallizations extracted from the mother liquors.

By this definite fractionization it is possible to obtain the concentration of a few centigrammes of almost pure radium bromide, to secure which it is necessary to utilize fifty-six tons of products: one ton of ore, five tons of chemical matter and fifty tons of water.

Although quite recently Madame Curie has succeeded in isolating pure radium, yet as employed in therapeutic work it is one of several compounds, such as radium bromide ($Ra\ Br_2\ 2H_20$); radium sulphate ($Ra\ SO_4$); radium chloride ($Ra\ Cl_2$); and radium carbonate ($Ra\ CO_3$).

An apparatus much used in the study of radium is the spinthariscope, an apparatus devised by Sir William Crookes to demonstrate the luminous qualities of the metal. It consists of a short brass tube, one end of which is closed by a convex lens, and the other by a screen of zinc sulphide, directly in front of which is placed a minute quantity of radium. Upon looking through the lens one sees the screen lit up by brilliant scintillations, each the effect of the impact of the alpha ray, thrust out in the disintegration of the radium.

Character of Radiation

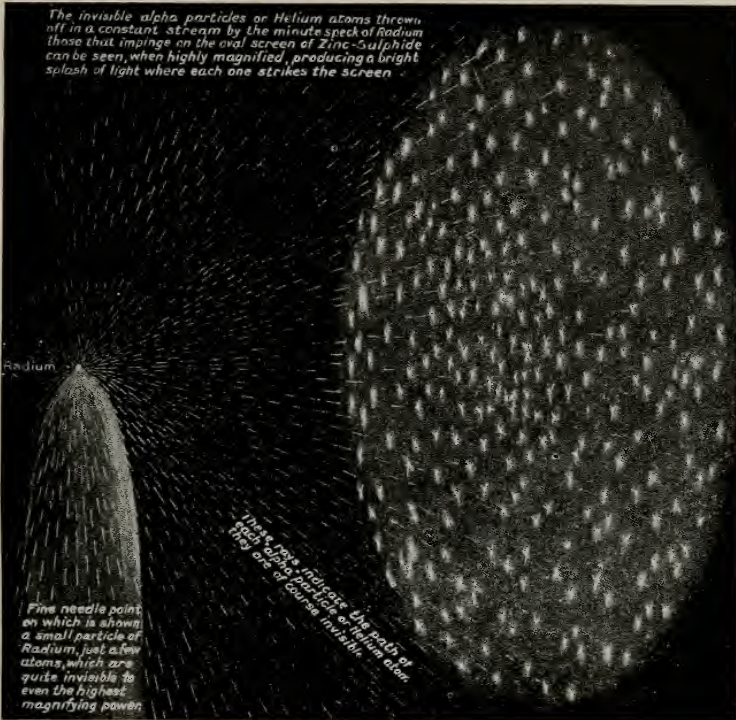
Radium is constantly undergoing disintegration, breaking up into inconceivably minute particles of matter that fly out from the mass at an incredible rate of speed, and consuming an energy that transcends the human imagination. And the wonder of it all is that this tremendous energy is emitted without cessation for 20,000 years; at the end of a "half-life" period, or two thousand years, half of it will have disintegrated; at the end of another two thousand years, half of the remainder will have disintegrated, half of the remainder at the end of another two thousand years, and so on until all has passed into decay.

Alpha Rays: This radiation is not homogeneous, but is made up of three kinds of rays, designated as alpha (a), beta (b), and gamma (y) rays, differing vastly in velocity, in penetrative power, and in therapeutic effects.

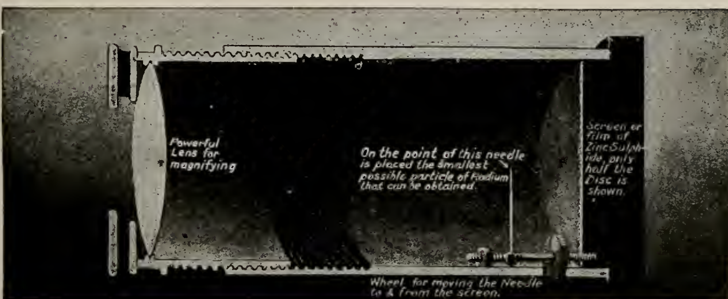
The *alpha* rays are made up of minute particles carrying a charge of positive electricity, and traveling at a speed of more than nine thousand miles a second. Their penetration is not great, however, for they are completely stopped by a sheet of ordinary note paper, by a sheet of aluminum .006 centimeters thick, or by three inches of air.

A fact of great interest to physicists is this, that many evidences seem to prove, either that the particles of matter which constitute the alpha ray consist of helium, or that the alpha rays are converted in radiation into helium, that strange element long known to exist in the sun and certain planets, but which until recent years was not known to exist upon the earth. The spectrum of helium has been found

STRIKING VISION OF THE RADIO-ACTIVITY OF AN ATOM



An invisible speck of radium throwing out invisible atoms that sparkle into sight on a film



THE SPINTHARISCOPE, WHICH ENABLES RADIUM PARTICLES TO BE SEEN SHIMMERING CLEARLY

These pictures show the means by which the marvelous energy stored up in radium may be observed. From a speck of radium too small to be seen a stream of helium atoms pours forth, and will do so for 2500 years before the radium ceases to exist. The flying particles fall on a zinc sulphide screen or film like hailstones splashing on the surface of water, and the splash is visible, while the radium itself and flying atoms are not. This is the nearest men have yet come to seeing an actual atom.

to appear in a tube into which radium emanation has been put, and if the process is one of conversion of radium into helium, scientists see in the phenomenon a fulfilment of the dream of the alchemists of all ages—the transmutation of a baser into a nobler metal, under the influence of the tremendous energy liberated by the disintegration of the radium atom.

Beta Rays: It has now been demonstrated that the beta ray of radium is practically identical with the cathode stream of the vacuum tube, but traveling with a much higher velocity. They have, owing to their greater velocity, a greater penetrability than the alpha rays, being to the latter as one hundred is to one. In therapeutics, three types of beta rays are recognized: hard, medium and soft, in the order of their hardness.

Gamma Rays: The *gamma* rays, unlike the *alpha* and *beta* rays, do not consist of material particles, but are electro-magnetic pulsations of the ether, similar to x-rays, light and Hertzian waves, probably originating in the explosion of the radium atoms in their disintegration. The *gamma* rays have a remarkable degree of penetrability. If we place a screen coated with barium platino-cyanide crystals in the dark, a metre away from a powerful radium apparatus, the screen is illuminated with a diffused light; if we lessen the distance, the light becomes concentrated and brilliant. This experiment shows that the rays have passed through the air.

Again, if we place a book, a stone, or any substance whatever (the experiment through a door or a partition wall is interesting), or interpose organic tissues—the human body for example—between the screen and the radium, the screen continues to be illuminated, and its refulgence is at the same time in direct ratio to the power of the radio-active sources, and in inverse ratio to the thickness or density of the interposed body. For this reason, certain substances, such as aluminum, mica, and certain varnishes, are easily penetrable, while others, such as lead, silver and platinum, offer, on the contrary, greater resistance.

Separation of Rays: This threefold composition of radium is important, since by proper means of separation the various rays can be isolated and applied therapeutically as the particular case demands. Thus, if it is desired to direct the *gamma* rays alone upon the body, a sheet of lead, say five millimeters of thickness, will cut out both the *alpha* and the *beta* rays; if it is desired to utilize the *beta* rays, a sheet of note paper or of aluminum or other metal of a certain thickness will cut off the *alpha* rays and permit the *gamma* and the *beta* rays to enter the tissues. Still another method of isolating the various rays is by means of magnetic deflection. If radiation is made to cross the space between the poles of a powerful electro-magnet, the *alpha* rays will be bent in one direction, the *beta* in the opposite, while the *gamma* rays are not affected electro-magnetically whatever.

Delta Rays: A group of rays called "delta" (*d*) rays by Professor J. J. Thomson, a famous English physicist, are set up by secondary radiation. When a stream of *beta* rays, for example, falls on matter of any kind, it is scattered widely in all directions, the scattered radiation giving rise to "secondary *beta* rays," and *gamma* rays giving rise in contact with matter to "secondary *gamma* rays." In a similar way very feeble "secondary *alpha* rays" are produced from *alpha* rays.

Radium emanation

A still more remarkable product of the rays is "radium emanation, or niton," a gas which is being constantly emitted by radium. And, strange to say, this gas, weight for weight, is one hundred thousand times as radio-active as radium itself, and, like radium, gives off *alpha*, *beta*, and *gamma* rays, first having gone through a group of intermediate substances known as radium A, radium B, radium C, radium D, radium E, radium F, and radium G (the accompanying chart shows the relation of these various aspects of radiation).

Radium
- Radium Emanations
  - Radium A, Radium B, Radium C, Radium D, Radium E, Radium F, Radium G
    - Alpha rays, Beta rays, Gamma rays
- Alpha rays, Beta rays, Gamma rays
  - Secondary Radiation
    - Secondary alpha rays, Secondary beta rays, Secondary gamma rays

Induced radio-activity

Still another type of radiation consists of what is known as "induced activity." So long ago as 1899 Professor and Madame Curie found that the surface of any body placed near radium, or immersed in radium emanation, acquires thereby a decided radio-activity. Water has been found to acquire radio-activity in this manner, a fact which has been utilized in the treatment of various disorders, as for instance at Hoachimsthal, where the spring waters become radio-actively charged by passing over pitchblende ore. As to the duration and strength of the radio-active property conferred in this manner, Wickham and Degrais have shown that these depend on the length and intensity of the contact, as well as upon the nature of the substances impregnated. When the emanation is separated from the radium its life is of short duration, and the induced radio-activity determined by the thus isolated emanation dies out rapidly. The loss follows a well-defined law of diminution. It is fifty per cent every half-hour as long as the body impregnated with radio-activity is not enclosed, while, if enclosed, the loss corresponds to only half the activity in four days. This is why the radio-activity of mineral waters does not last when taken from their source.

If the emanation remains in proximity to the radium so that it is replenished in proportion to its loss, the radio-activity produced is more constant. For example, when the radium atom is introduced into the tissues of the body the sources of induced radio-activity are much more lasting.

Therapeutic application of radium

Thus, in the therapeutic use of radium the physician has a wide variety of applications from which to choose: the *alpha*, *beta* or *gamma* rays, or all three combined, the secondary rays, radium emanation, and induced radiation. Strange to say, however, the therapeutic value of radium was not discovered until 1901, three years after the discovery of radium by the Curies. In that year Becquerel visited London, carrying in his waistcoat pocket a small tube containing a minute quantity of radium. He soon became conscious of a soreness at the point of his body against which the small tube of radium had pressed. Examining the spot he found the flesh inflamed, and came to the conclusion that the burn was caused by the radium. This inflammation, which has become famous as the "Becquerel burn," gave rise to an extended study of the effect of radium on tissues of the human body, especially with reference to its use in the treatment of disease.

Professor Danysz, of the Pasteur Institute, Paris, found that three hours' exposure to radium was sufficient to give rise to painful inflammation. In experiments upon a guinea pig he found that minute amounts of radium sealed in a glass tube and placed against the body would burn off the hair and produce a painful disturbance of the tissues, which, however, would feel like any other sore.

The results were scarcely less remarkable in the case of experiments upon young mice. Placing radium a few inches above the animals, he found that the mice became "dopey" within a short time, paralysis of the hind legs followed, with convulsions and ultimate death. Larval worms which he subjected to radium were likewise affected, many of them dying and the others showing retarded development. Those specimens which were not treated with radium grew into normal beetles.

The Treatment of Cancer

These experiments showed conclusively that radium has a very vital effect upon healthy human tissue, and attention was centered at once upon the possibility of curing cancer by the new method. Study was first made of such abnormalities of the skin as warts, and these, it was found, reacted at once to the effects of radium, after one treatment disappearing in a very few days. Attention was next turned to those tumor-like growths which frequently appear on the face. These had been successfully removed by the surgeon's knife, but often at the expense of a horrible disfigurement of the part. If no trace of the tumor was left in the system, the cure was permanent, but, as too often happened, it was not entirely removed, and the growth reappeared.

In the treatment of this type of cancer, radium has achieved wonderful results. In the deeper-lying tissues, however, the cancer is less easily reached, and the difficulty is thus increased manifold, although here remarkable results have been secured. One of the early experiments was upon a youth of seventeen, who had a rapidly growing cancer on the lower jaw, a "giant-celled" type of tumor of great malignancy. An operation was apparently the only means of saving the patient's life, and the success even of this was entirely problematical. Radium was applied, and after a few applications the cancer entirely disappeared and normal, healthy bone grew in its place.

Except in a few rare instances, such as growths of the palate, tonsils and gums, the results of radium treatment of cancer of the mouth have not been very satisfactory.

In the treatment of deep-lying and malignant cancers, such as cancer of the breast, cancer of the pelvic organs, etc., the efficacy of radium is still undetermined, though this much is known, that it reduces pain, and retards the growth of the tumor, even in the most obstinate cases; and there have already occurred a number of authenticated cures.

Radium Treatment of Rheumatic Conditions

Radium emanation has also been used with some degree of success in rheumatic conditions, notably by Dr. Paude and others in the treatment of arthritis deformans, subacute and chronic rheumatism, gonorrheal rheumatism, neuralgia, and such cutaneous affections as pruritus. A form of application used extensively in these disorders is induced radio-activity; that is, by bathing the patient in water which, by its contact with radium or radium emanations, has acquired a radio-activity of its own.

But, after all, the most momentous results have been obtained in experiments upon cancer, owing partly to the fact that a cure for this horrible malady is being sought with greater and still greater eagerness by scientists, and also by the further fact that the *gamma* rays seem to have an affinity for the cells that make up cancerous tissue, a fact demonstrated by the phenomenon that *gamma* rays pass through surrounding healthy tissue and leave them unharmed, but penetrate and destroy at once the diseased cancer tissue. The rays seem to find some substance in the diseased tissue that it does not find in the healthy tissue, and proceeds to destroy it.

Difficulties of Standardization

One of the greatest difficulties that has stood in the way of the therapeutic use of radium has been the fact that standardization has developed slowly. The variation in strength of the various rays, not only of the radium itself, but of radium emanation and of induced and secondary radio-activity, under varying conditions has made it difficult to apply any forms of the metal with any degree of accuracy.

There is the further fact, too, that *alpha*, *beta* and *gamma* rays have entirely different effects upon body tissue, whereas the physician in the early experiments applied all three rays indiscriminately to the affected tissue, unconscious of the fact that one ray might act quite differently from the others, and produce harmful effects.

The *alpha* rays, owing to the fact that they cannot penetrate deeply into the tissues, have little effect beyond inflaming surface tissue, as in the case of Becquerel burn. The *beta* rays, again, have a particularly stimulant effect upon growth when applied to plant equally with animal cells. Oats, for instance, when subjected to the influence of beta rays, have been found to grow much larger and develop more fully than ordinary oat plants. Again, in some cancer cases treated with radium, the effect was found only to increase the virulence of the lesion and to hurry the patient's death.

As soon as these facts became known, the attempt was made, of course, to isolate the various rays, and to make it possible to treat when necessary any diseased tissues with *gamma* rays exclusively and in any strength desired. A means of accomplishing this with some success has since been discovered, as we have found, both by using metal plates or other substances of varying degrees of thickness, or by means of electromagnetic deflectors. Thus satisfactory standardization seems assured in the future, when emanation and induced radio-activity can be brought under equally complete control.

The Conservation of Radium

The problem of a more exact application of radium has taken on new interest through the efforts of leading American radium workers to conserve, by national means, the sources in this country of carnotite ores, and thus to make accessible to American physicians a larger supply of radium. Dr. Howard A. Kelly, of the Johns Hopkins University, is sponsoring the movement, and believes that radium has only to be produced in sufficiently large quantities to make its benefits universally accessible.

It is the concensus of opinion of experts that enormous doses of *gamma* rays can be given without injury and that the favorable results in successful cases have been due to the fact that very large doses have been used. The extreme rarity of radium makes it physically impossible of occupying the widest field of usefulness, and this limitation is increased by the consequent price, which was recently quoted at $120,000 per gram.

SCENES FROM THE MOVING PICTURE WORLD

MOVING PICTURES—THE WORLD IN REVIEW

A QUARTER of a century ago animated photography, or the moving picture, was an undreamed dream. Today, though an impressive reality, it is still marvelous.

Professor Frederick Starr, the noted traveler and sociologist, has very graphically characterized it thus:

"I have seen Niagara thunder over her gorge in the noblest frenzy ever beheld by man; I have watched a Queensland river under the white light of an Australasian moon go whirling and swirling through strange islands lurking with bandicoot and kangaroo; I have watched an English railroad train draw into a station, take on its passengers and then chug away with its stubby little engine through the Yorkshire Dells, past old Norman Abbeys silhouetted against the skyline, while a cluster of century-aged cottages loomed up in the valley below, through which a yokel drove his flock of Southdowns; I have beheld fat old Rajahs with the price of a thousand lives bejewelled in their monster turbans, and the price of a thousand deaths sewn in their royal nightshirts as they indolently swayed in golden howdahs, borne upon the backs of grunting elephants; I saw a runaway horse play battledoor and shuttlecock with the citizens and traffic of a little Italian village, whose streets had not known so much commotion since the sailing of Columbus; I know how the Chinaman lives and I have been through the homes of the Japanese; I have marveled at the daring of Alpine tobogganists and admired the wonderful skill of Norwegian ski jumpers; I have seen armies upon the battlefield and their return in triumph; I have looked upon weird dances and outlandish frolics in every quarter of the globe, and I didn't have to leave Chicago for a moment.

"No books have taught me all these wonderful things; no lecturer has pictured them; I simply dropped into a moving picture theater at various moments of leisure; and at the total cost for all the visits of perhaps two performances of an ordinary show, I have learned more than a traveler could see at the cost of thousands of dollars and years of journeying."

The moving picture industry makes for us volumes of history and action. It gives a great variety to the themes of entertainment and is at the same time a mighty force of instruction. We do not analyze the fact that when we read of an English wreck we at once see an English train before us, or when we learn of a battle that an altogether different panorama is visualized than our former erroneous impression of a hand-to-hand conflict; we are familiar with the geography of Europe; we are well acquainted with how the Frenchman dresses, in what sort of a home he lives, and from what sort of a shop he buys his meat and greens.

Today the moving picture industry is developed to a high degree of perfection in America and Europe. Millions of dollars are invested in the production of moving picture films; entire companies of trained and practiced actors are carried to every interesting spot on the continent and carefully drilled to enact pantomimes which will concentrate within the space of a few minutes the most entertaining and instructive incidents of the world.

HOW IT WAS DISCOVERED

The basis for animated photography—or the continuity or persistence of human vision—was noted by the famous Arabian astronomer, Ptolemy, before the Christian era. The retina of the human eye has the psychological property of retaining for a brief time, the tenth of a second the impression of an image after the object which produced it has disappeared. If these images are shown representing successive positions assumed by the object in motion, the impression conveyed to the eye is that of continuous movement without intermission.

No practical use of the observations of the ancients was made up to the middle of the eighteenth century, at which time a scientific toy called the "Dream Top" was evolved in France. This had an added charm in 1829, when another scientist invented the Phantoscope, a disk revolving around eight spokes viewed the perforations

A MOVING PICTURE STAGE

This shows how the stage is artificially illuminated. The artificial lighting equipment in the main Selig studio is only used when the sunshine is inadequate. A traveling frame holds 15 quartz tube Cooper-Hewitt lights, each bearing 4500 candle power, being in a space 12 feet square 10 feet above the scene. On either side of the scene are banks of mercury vapor lamps (with tubes 50 inches long); this floods its limited stage section with approximately 100,000 candle power.

in the edges. In 1841 photography having come into the possession of the people, photographs were substituted in this device for drawings.

The next most important move, in a great invention, was made by Edward Muybridge, official photographer of the United States Government, who, in 1872, made a series of practical experiments in which cameras caught the movements of horses in motion, reproducing what he called "animal locomotion." In this Muybridge utilized twenty-four cameras, engaging in their process certain springs, which struck by the passing animals, released the shutters of the cameras, catching the particular pose of the passing instant.

THE CELLULOID NEGATIVE

It was not, however, until 1889, that Friese-Green and Evans patented a machine in England for taking pictures on celluloid—that this substance became the invaluable substitute for glass, in photography. This made it a comparatively easy matter for a long series of negatives to be taken upon a continuous, transparent, flexible support which became the perfected base of moving pictures.

IMPROVEMENTS OF EDISON AND LUMIERE

In 1893, Thomas A. Edison invented the kinetograph and two years later Lumiere in France, who had been working independently along the same line, exhibited his kinometograph in Paris. The American, commercially and practically, demonstrated the possibilities of a new invention and consequently Edison gets a royalty from all film users for his perforation in the edge of the film, which holds it steady and eliminates the jumpy side motion that used to be so distressing in the showing of films. Lumiere introduced the drop-shutter, which disguised the hiatus involved in the change of pictures. Since then the Selig polyscope and numerous other motion picture machines have appeared with numerous new and valuable improvements that have added immensely to the vital illusion and the artistic conviction imposed by the flying film.

MECHANISM OF THE CAMERA

The celluloid film upon which the photographs are taken, is one and three-eighths inches wide, is in rows of two hundred and four hundred feet in length and certainly has a tensile strain equal to that of linen paper, which is said to be over seven hundred pounds. This film is perforated on each side in successive areas three-quarters of an inch deep, the equivalent of a picture (eighteen perfect pictures to a foot), so that it can be seized by the running sprockets and brought taut into position behind the lens (sixty-four perforations to the foot is the Edison standard gauge). Nearly all the picture film made in America is manufactured in one establishment.

The mechanism of a cinematograph camera, seems comparatively simple, yet the Selig cameras are adjusted to a thousandth part of an inch, showing their accuracy of graduation. These cameras hold two film boxes—the upper for carrying the unexposed film —the lower for housing the exposed product, working upon the system of roller photography. The lens is set centrally in the front face of the camera with focusing effected by moving the lens itself. It is additionally fitted with stopping facilities on the well known Iris principle. The mechanism with an intermittent motion, pulls forward the film three-quarters of an inch after each exposure, the film passing through a narrow slit from under the unexposed film box over a sprocket wheel kept in firm mesh by a guide-roller, so that the film is moved and exposed with mathematical accuracy through the swinging gate when the exposure takes place and then, by a similar process, is drawn safely into the lower film box. This is mounted on a special heavy tripod, so that the camera can be swung panoramically or be moved through a large vertical arc.

The developing, printing and tinting of the films, is an involved scientific process conducted upon a large, but accurate scale. A large plant frequently develops and prints upwards of 300,000 feet of film in a week.

Present extent and future possibilities of motography

Although the art of motography in its large appeal to the public is less than ten years old, its serious, scientific development is said to now represent an investment in this country alone of over $50,000,000.00 in expensive plants equipped with special and elaborate machines. Up to date there is said to be fully 30,000 theaters in the United States devoted to the use of moving pictures. The producers and manufacturers of moving pictures have kept pace with the growing demands of an eager and appreciative public in regard to the interest and the quality of their product. In the vast domain of picture play, they have enlisted stock companies for the silent drama that have in them the best Thespian talent procurable and the great stars of the stage are now appearing in such productions to make pantomime a more poetic and potential attraction than ever before. The motion picture business has a broader, a more serious and a more lasting value in the educational way. Historical dramas, great events of national importance have an influence too infrequently considered, but have enduring qualities that promise to add greatly to the world's store of knowledge. The so-called travel films are an equally valuable asset, as they concern the intimate information for the public in bringing on the beauties of nature and the wonders from the far corners of the earth for the observation of every community. Another form of the informing values of pictures come through the study of natural history, scientific and microscopic investigation. The delicate art of the surgeon is now brought to the attention of the medical student through the searching eye of the camera, while the study of bacteria is microscopically accomplished through the same wonderful medium. These good and great accomplishments of motion pictures are adding vastly to general interest as well as to the knowledge of the scientific world.

When photography is accomplished in color, when the film becomes unbreakable and can be perfectly synchronized with the talking machine, the moving picture will approximate perfection in its impress upon the human eye and ear. It has already accomplished marvels, yet still appears to be upon the threshold of greater things.

How the picture plays are staged

In the taking of moving pictures, the camera is ordinarily placed fifteen feet from the stage to show people at normal height, the front line or footlight of the scene being only eight or ten feet wide. The interiors are set at an angle and are consequently open on two sides and at the top, so that the scene gets all the illumination possible. Such surroundings limit the radius of action although any depth may be used for value in perspective. Naturally, out-of-door productions allow the widest liberty of action and a

BEHIND THE "FOOTLIGHTS" OF THE MOVING PICTURE STUDIO

Actors waiting their call in the Selig Studio. This stage is 90x150 feet, and admirably sky-lighted sweep to the horizon. If the picture of persons at fifteen feet distance reveals them life-size, when a long focus lens is used and they are photographed at a distance of a hundred and fifty feet, they resemble Liliputians—an advantage frequently used in the production of fairy plays.

The actors engaged in picture-plays make up less strongly than they do on the theatrical stage, as the lighting is more intense and the camera catches every detail. It must be remembered that in the moving picture film it is impossible to rectify any mistakes by re-touching. The actors move and speak (usually extemporizing) as they do in life, simulating all the emotions to make pantomime telling and potential. Before filming a silent drama, the actors are thoroughly rehearsed in every detail of the "business," by the director who times the scene accurately and calculates the film footage in advance. In important scenes, usually two or more cameras are called into use, so that choice of films may be secured from slightly different viewpoints.

Picture stage settings

The settings of studio scenes are painted in neutral tints of browns and grays like photographic backgrounds, and are frequently most elaborate in construction, while the furnishings may be of the richest character. While no charm of color obtains in these photograph scenes, the actors are as richly and as correctly costumed as they are upon the mimic stage and no effort or expense is spared to make the ensemble equal, if not superior, in every detail to their theatrical prototypes.

In this country films are tinted to secure the effect of twilight, of moonlight, the glare of a conflagration, or the cloud-gathering of a storm. In Italy, this scientific process has developed through "toning" and almost stereoscopic values for films. The Cines Company of Rome, have been singularly successful in this artistic touch. The French secure delicate and varying effects of color through tiny stencils applied to the films, the printing process involving aniline dyes, being similar to that employed in the larger scale of placing patterns on wall-paper. At present kinemacolor is the best known commercial natural color system. Some of its effects are beautiful, although the process has not yet been perfected.

Large stock companies are employed for regular daily service, the morning hours being obviously the most valuable, by reason of the sunlight. Now, however, all studios are fitted with Cooper-Hewitt quartz burners as well as mercury tube lights, so that the artificial illumination is more brilliant even than that of nature. The selection of actors is by no means easy, as the taxing peculiarity of the cinematographic stage is that the actor must not only act, but look the part—types are in great demand for character work in the silent drama.

The curious public, frequently believing that the camera lies, ask doubtfully: "Are these things real? Do those engaged in the moving pictures do the things they seem to accomplish? Are there any risks or real dangers?"

Such inquiries in the broad can be emphatically answered in the affirmative; although the manipulated camera and the printing of films may secure very puzzling and uncanny results. The wild rides, the strenuous experiences enacted, are real, although they may be of short duration. The bucking broncho, the speeding train, the racing automobile, or the flying airship caught upon the film, is in no sense counterfeit.

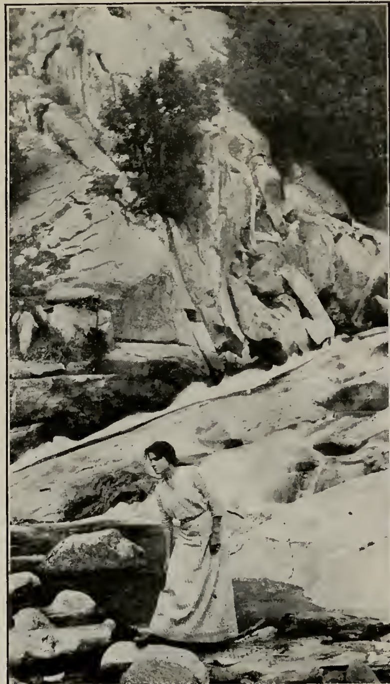
STAGING FOR PAULINE CASHMAN IN "THE YANKEE SPY"

When Tom Mix, the champion cowboy, unlimbers for action, he leaps from a running horse to the back of a frenzied Texas long-horn and actually accomplishes what is known in the technic of the ranch, as "bull-dogging" a steer. This means that the daring rider, with his bare hands, hanging on to the horns of the maddened animal, brings it to a standstill and actually throws it to the ground in front of the recording camera, a very difficult feat. It was an extraordinary bit of daredeviltry that inspired this cowboy to the ordeal of being thrown from his horse, allowing his foot to catch in a stirrup and be dragged—a dreadfully hazardous stunt. While blank cartridges are used in battle scenes, like the charges for artillery, and coils of worn-out film are fired by electric contact to give the effect of exploding shells, real bullets are frequently used in wild west gun-plays, that toss up the dust and clip the rocks close to the combatants. In such scenes only skilled shots are employed and men willing to take the risk.

Securing local color

While much work is done in studios during the winter season, companies travel great distances and there is no caviling at expense when it comes to securing proper "locations." Many out-of-the-way sections of the world have been visited to secure effective environment for picture plays. A well known American producer recently purchased a large estate in Turin, Italy, which he will utilize for its pictorial values in play-craft. The Selig Polyscope Company, for example, in addition to its square in Chicago, and a similar size plant in Los Angeles, California, has the Selig Zoo, a tract of fifty acres, planted like a botanical garden, fully stocked with the rare wild animals of Asia and Africa. In this collection are forty lions, ten leopards, six tigers, as many

The caravals used by the Selig Polyscope Co. in "The Coming of Columbus."



Natural scenery location in the Rocky Mountains

Scene from "Monte Cristo," being taken at Selig's Los Angeles studio.

elephants, giraffes, hippopotami, rhinoceroses, and other habitants of the tropics. Selig was the originator of the wild animal play and has expended a great deal of money to make the encompassment of these realistic productions true to nature in every fidelity of detail. In "The Adventures of Kathlyn" and a series of unique and thrilling predecessors located in jungle land, all the animals utilized, including the most dangerous and treacherous carnivora, were unfettered, making the hazards of such productions dangerous beyond compare. Naturally, these animals, which are not trained animals, are kept within bounds, but they are not restrained by tethers.

Moving-picture actors have a deep dislike to "water-stuff" which involves discomfort and danger. When the tank lakes in studio yards are used, risks are largely eliminated, but out on the high seas the chance changes. Many notably fine effects have been secured off rock-bound coasts, splendid in atmospheric value, or out on blue water. Few picture plays have been more impressive than the ship reel in "The Coming of Columbus," in which the caravals, replicas of the original craft, were utilized in most realistic fashion. Operations with maritime craft in miniature, are frequently filmed, but they are seldom convincing, as many chances are open to show their unsubstantiality.

The demand for realism is great and growing, and shrewd producers dare all sorts of conditions to secure the truth that thrills triumphant. The kerosened interiors of houses built only to burn, with flimsy sheet-iron walls designed to fall, or miniature model towns made of cardboard, have served their mission many times. One day a fire broke out in a large department store in Los Angeles, and an enterprising picture-play producer, accompanied by his camera men and leading people, rushed to the scene and, through the sanction of the firemen, and the intrepidity of the leading lady, secured her rescue from an upper window surrounded by the actual fire. Many fierce oil-tank fires have been filmed to serve as a background of plays at later days; in fact, the oil-fire is a sort of stock fixture for intermediate scenes of the fire story.

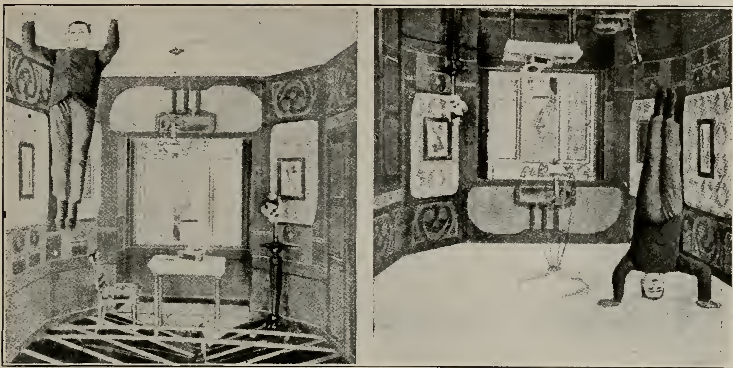
How the "Impossible" Pictures are Obtained

Interesting illusions have been impressed through what is known as "stop motion," "double printing" or "stop and substitution." Trick pictures using these effects, have been chiefly evolved in France, where labor is cheap and time is not grudged for securing minutia in recording every move. Some examples may be recalled in "The Traveling Bed," "The Magnetic Man," or "The Magic Laundry."

In the first named play, when bailiffs come to the scene to eject a tenant, they are spared trouble by the animation of furniture, which moves out of the room in methodical order followed by the bed with the tenant in it. Wires move all the smaller objects and the bed is pushed along by stage hands concealed under it.

When "The Magnetic Man" strolls down a Parisian street in a coat of mail, metallic articles seem to jump toward him and cling to his person. To one and all of these articles invisible wires are attached, the free ends being held by stage hands, or by the principal himself. When the cover of a manhole in the sidewalk rises on edge and bolts after him, it is manipulated by wires held by the actor. After the cover is raised, a "stop" is made, so that the stage-hand can enter the picture and start the wooden

HOW MOVING PICTURE TRICKS ARE DONE

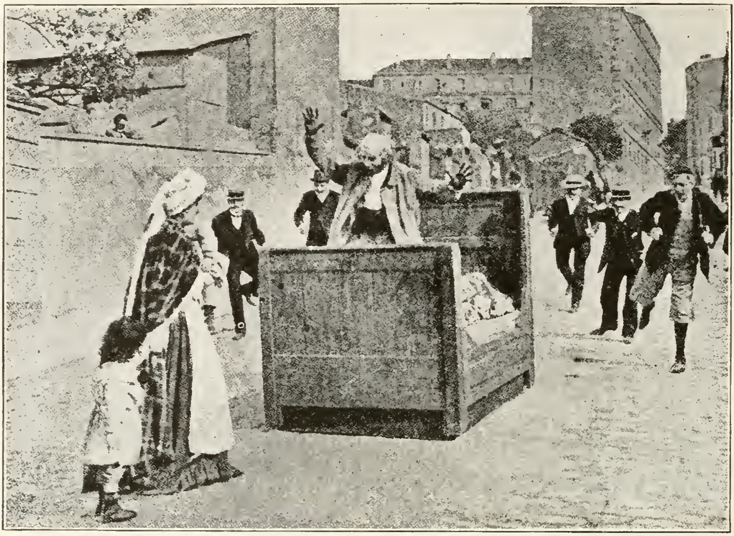


The walker on the ceiling seen here is photographed walking on the floor as seen here

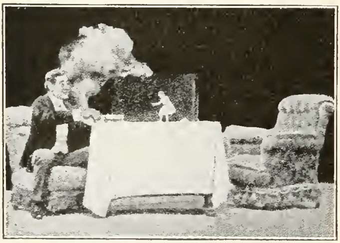
The ski-runner is photographed on a film that already has the chimney and clouds

The magnetic man really draws shop signs, cellar doors and lamp posts toward him by thin wires

THE IMPOSSIBLE MADE TO SEEM REAL

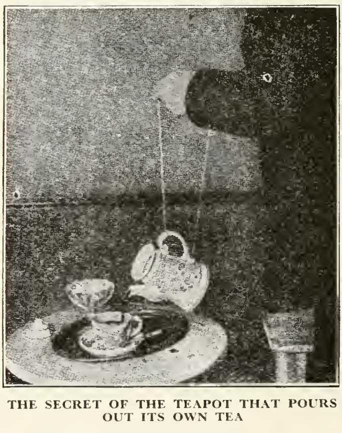


THE BED THAT RUNS UP THE STREET—IT IS REALLY BEING PUSHED FROM BEHIND



THE FAIRY WALKS ACROSS THE TABLE

THE FAIRY DANCES IN THE BOTTLE



THE SECRET OF THE TEAPOT THAT POURS OUT ITS OWN TEA

cover, painted to resemble iron, rolling. The lamp-post that jumps toward him is snapped in twain, by strong wires attached, having been previously hinged to heel over like a flap.

In the laundry where articles go through the process of sorting, washing and ironing without any visible human agency, each movement of each process was photographed, "stopped," then the action was resumed, all representing remarkable care and vast pains to make its mystery baffling to the eye, through the complete continuity of action. The "stop" movement, as a rule, is the secret of all instantaneous disappearances.

Astonishing and highly ingenious effects are obtained by "the reversal of action" in running a film backward. All objects it depicts, act topsy-turvy and defy the laws of gravitation. Pedestrians walk backward, automobiles whirl back in dangerous zig-zags and smoke instead of escaping from chimneys seems to flow downward. Objects are seen to roll up-hill in a race, or fly violently into the air, while a brick wall builds itself. These pictures were all taken in the reverse and the brick wall had its demolition really photographed.

Audiences are puzzled by the antics of cyclists or motorists, who elude the capture of pursuing crowds, by turning their vehicles and running up vertical walls to cloud-land. In such cases, a cloth, carrying the painted impression of the wall with its windows, stack-pipes and architectural projections, is laid upon the floor of the studio and the camera is pointed down upon it from the "flies" above. It photographs the vehicles driven over this ground cloth, so that the film conveys the impression of their scaling the wall. Escaping prisoners, comical soot-covered men, laboriously worming their way up narrow passages or chimney flues, work through similar devices, as they are merely stage properties laid upon the floor and photographed from above.

The present effective camera mechanism, allowing double exposure, does away, to a large extent, with the slow, old forms of double printing; so that wonderful transformations are secured and beautiful dissolves are obtained that far outdo ordinary stage effects for interesting and astonishing combinations in vast variety.

The sensational and amusing side of motography has its fascinations, but the art has a higher aim in its scientific and informing phases. It may show the growth of a flower, the wonder of the silk worm, weaving its own sarcophagus, and through the microscope revealing nature's hidden secrets. Thomas Alva Edison declares that animated photography is destined to become the greatest factor of education in the future.

MEASUREMENTS OF TIME

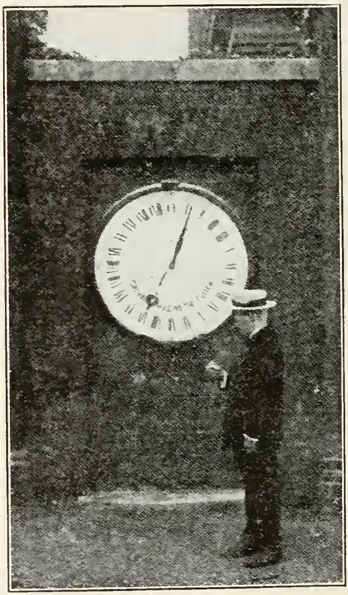
THE sun by day, and the moon and stars by night, send to us something more than the visible light that strikes our eyes. From them comes a subtle radiance which enlightens our minds. It was from the heavens that man obtained that idea of time which was absolutely necessary for the development of his intellectual faculties. He had to find some way of measuring the succession of things before he was able to attempt to control any of them. Isolated at first in the midst of a world in which everything was to him a mystery, and terrified at every unexpected manifestation of natural forces, primitive man was incapable of seeing in the course of the universe anything but caprice.

The alternation of day and night, and the recurrence of the seasons, were no doubt the first thing that enabled man roughly to measure the passage of time. But this carried him very little farther than some animals get. The curious instinct of a recurring change that sends the swallow on its far migrations was not sufficient for intelligent human purposes. Man needed both a finer and a larger instrument for measuring time than the periods of light and darkness, and coldness and warmth, that govern the activities of plant and animal. Compelled by his growing intelligence to search for the reason of things, he suffered great moral and intellectual injury through his long failure to measure time. He could not parcel out space intelligently in the absence of some means of defining the duration of objects; and his powers of memory were confused by his lack of a fixed standard of the efflux of time. Being unable to remember distinctly, he was unable to foresee clearly.

THE STARRY HEAVENS THE FIRST CLOCK

It was by the study of the recurring phases of the moon that primitive man seems to have made his first great advance. By lunar months a good many uncivilized people still measure the longer lapses of time. It was more difficult to find a way of dividing a single day into small, regular periods. For the daily course of the sun from the eastern to the western horizon varies considerably in most parts of the earth. The rising point and setting points are quite different in winter and summer, and the course of the low winter sun is much shorter than that of the high summer sun.

The shadow thrown on the ground by a tree or an upright stick does not travel over equal distances at an equal



The clock at Greenwich, England, which gives the standard time to the world

BEHIND THE GREAT FACE OF BIG BEN

At the top of 360 steps in the Clock Tower at Westminster, Big Ben has marked time for London for fifty years. It is not possible to understand the size of the clock as we stand on the ground. It has four faces, each 23 feet across—nine or ten times as wide as a door. The minute hands are 14 feet long; they would reach higher than an ordinary room. The pendulum weighs nearly 450 pounds. The figures on the face are each two feet long, and the minute spaces are a foot square. If you will look closely at your watch, you will see the minute hand move in little jumps; the minute hand of Big Ben jumps half a foot every time it moves. It is not easy to believe these figures, but that is because our eyes deceive us when we look up to a great height, and Big Ben stands so high that if thirty tall men stood on one another's shoulders the top man would only just touch the middle of its face.

speed. So this primitive form of sundial was not useful as a teller of the passing hours of daylight. It was not until man grew studious of the spangled darkness of the midnight skies, and began to study them on clear, unclouded nights, that he obtained that vision of a reign of universal law which he could not discern on the earth around him.

On considering the midnight sky attentively, he perceived that the stars were not a confused multitude of lights wandering at a venture, but a disciplined army that marked by its march the regular passage of time. Against this majestic revolution of the heavenly sphere, with its awe-inspiring regularity of motion, the different annual courses of both the sun and the moon stood out clearly. As soon as the star-gazers gave themselves up to their work, they discovered that the sun could be regarded as the hand of a yearly clock, that showed by its position in the celestial track the month and season. Of course, it was impossible to observe the sun and stars at the same time, and it would have been much easier to have studied the moon alone as the clock-hand. But in scarcely any case of which we know anything was this done. The sun's path among the stars was divided into twelve portions, each corresponding with fair approximation to a month.

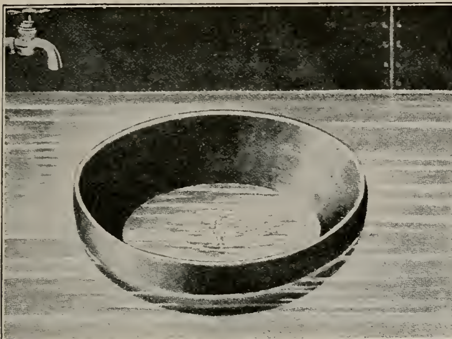
THE EARLY RECORDS OF THE HEAVENS

Two methods were then used in ascertaining the time of the year. Some early astronomers rose up before dawn, and made observations of the last conspicuous star rising just before the sun. The other school of time-measurers did their work in the evening, and associated the sun with the constellation that set just after sunset. After mapping out the constellations, directly associated with the yearly and monthly course of the sun in the skies, it was a simple step to study a few other star groups in other parts of the heavens. In the south there were some very bright stars, whose risings and settings gave an indication of the time of year; while in the north there were many stars that did not set at all, so that their slow motion had a special value for the nightfarer and the sailor.

All this was done in widely separated parts of the earth—in Babylonia and in Egypt, in India and in China, among the Incas of Peru and the Aztecs of Mexico. The South Sea Islanders and the ancient inhabitants of Britain both worked out the astronomical method of measuring time; and so did other barbaric and even savage races. Whether the great work of thus rescuing mankind from a world of timeless chaos and placing him in a universe of heavenly law was performed by some single nation of civilizing genius, whose discoveries were gradually spread among other people; or whether the common result was obtained independently at different times by different peoples is a problem that cannot be solved. There are, however, some good grounds for supposing that the Egyptians, Indians, and Chinese have made false claims in regard to the immemorial antiquity of their astronomical studies.

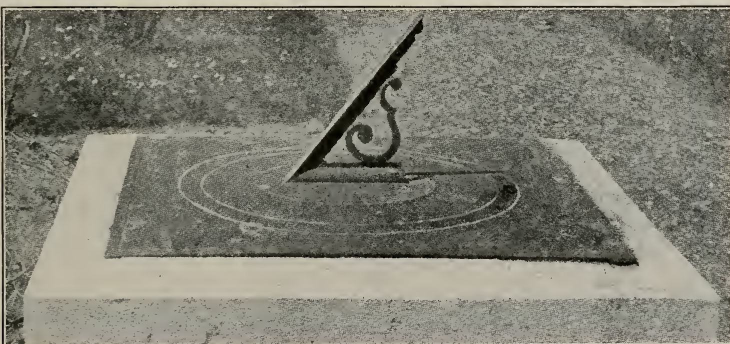
On the other hand, the system of the Babylonians stands examination, in spite of the fact that the Babylonian priests modestly informed Alexander the Great that their astronomical records went back 403,000 years. For it seems highly probable that about four thousand years ago the early inhabitants of Babylonia fixed and named the chief constellations that mark the annual path of the sun. The star groups which were afterwards added were too far south of

HOW TIME IN PAST AGES WAS MEASURED BY THE SUN

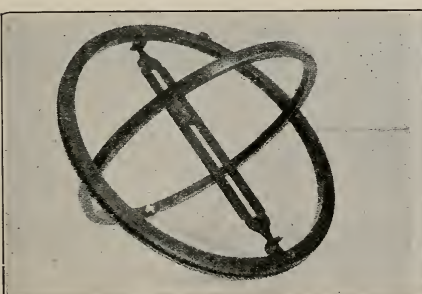


Time was measured for ages and ages by placing a small dish or a round basin in water and boring a hole in the bottom of it, the water flowing in, and gradually sinking it. This would always happen in the same period of time, so that men knew the time when the dish or water-clock sank.

This is a tiny rushlight holder. A rushlight was used before candles were made. It burns regularly, and was used by the poor for a long time after candles were invented.



There are very few people who have not seen a sundial, either on a house, or on a pedestal in a park. The dial is marked, and the time is told by the shade of the pointer falling on the different numbers.



This is a kind of movable sundial, which can be held up so that the sunlight shines through a tiny hole in the straight piece of metal, and lights up one of the figures engraved inside of the circle, which is placed at a right angle to the straight piece.

This is a primitive watch. It was always held in one position, and the sun, shining through the little hole, fell upon one of the numbers engraved on the inside of the circle, as shown here.

Babylonia to be visible in 2000 B. C.; and the period that elapsed before they were included in the modern method of measuring time is a piece of striking evidence in support of the claims of the Babylonian stargazers. There is even some truth in their contention that their astronomical calculations extended back for over 400,000 years. With the knowledge they amassed concerning the sun's apparent path through the heavens, they worked back and verified, to within a few years, the solar position, such as would be indicated on a sundial.

The invention of a proper sundial was only possible among a nation with a knowledge of the sun's apparent movements against the starry sphere; and it is possible that the Babylonians accomplished it. It is only at the North and the South Poles that a stick stuck upright in the ground will indicate by its shadow the regular passage of the daylight hours. In lower latitudes the shadow cast by the upright rod or style of a sundial would so alter its position at the same hour, at various seasons of the year, that the instrument would be useless. For instance, at nine o'clock on a midsummer morning the shadow would fall a good distance away from the spot it would occupy at nine o'clock on a midwinter morning. So the marks on the dial would be very misleading. To make a proper sundial, it is necessary to calculate the different paths that the sun takes in its high summer course through the sky and in its low winter journey. It is easily done by giving the rod or style of a sundial the same direction as the axis of the earth. This sounds very difficult, but in practice it only means that the style should point to the Polar Star. The position of its shadow in the sunlight will not then alter with the varying path of the sun. The shadow at nine o'clock on a sunny winter morning will fall upon the same line as the shadow falls on a bright summer morning. The task of drawing the hour marks on a dial is more difficult, as these occur at irregular intervals, instead of being evenly spaced round the dial.

PRIMITIVE FORMS OF THE SUNDIAL

But the savages who lived in prehistoric times in Great Britain seem to have worked out part of the difficult art of making a sundial. Some time ago there was published an abstract of some results of the excavations that Dr. McAldowie recently made in prehistoric burial mounds in Staffordshire and Gloucestershire, England. At Camp, the doctor uncovered a huge, rough stone monument, which clearly seems to be a very ancient instrument of time measurement. It consists of four stones, placed north, south, east, and west, and embedded in the solid rock. A leaning stone crosses in a diagonal manner the space formed by the outer stones. The structure is so built as to mark the turning points in the sun's annual path; but its most interesting feature is the way in which the hours are indicated at certain times in the year by shadows falling on prominent points or edges of the monument. The north stone is really a sundial, and the south stone a style, while the east and diagonal stones fulfil both purposes. The structure thus appears to have been a sacred instrument used for measuring the time at certain critical periods of the year, some of religious and some of agricultural importance. Dr. McAldowie has uncovered several other burial mounds, and found beneath them other big, rough stone-dials. He thinks they were the sacred places or temples of a very early race, and that they were converted into burial mounds by some alien invaders, who took over, as is often the case among ancient races, the traditions of sanctity attaching to the monuments.

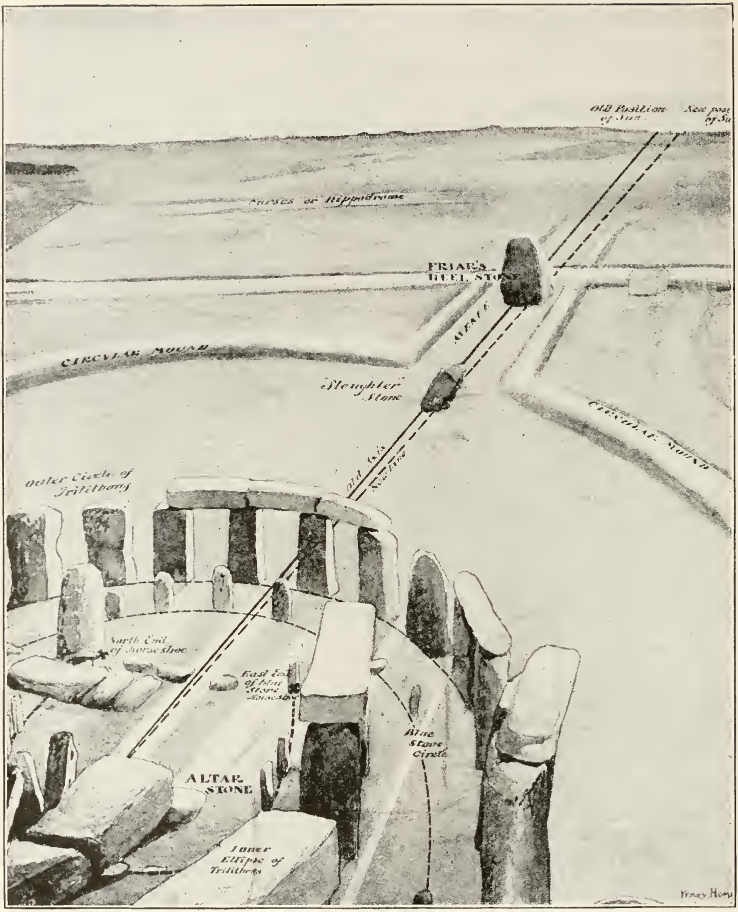
It scarcely seems possible that these buried structures should all by mere chance be admirable sundials. The real question is whether they are later in date than Dr. McAldowie supposes. Many so-called Druidical remains in the British Isles were probably in existence before the Celtic peoples and their medicine-men, the Druids, invaded the country. The Druids, no doubt, took over the traditions of sanctity attaching to Stonehenge and Avebury, and other similar prehistoric monuments; and it is quite likely that in some cases they may have continued, and improved upon, the work of the earlier builders. But on the whole doubtless most of these strange monuments were the work of a native, non-Celtic people of the New Stone Age. It is possible that this prehistoric British race was not far behind the civilized farmers of Southern Babylonia, in marking the annual path of the sun amid the stars, and putting their knowledge to good use in the erection of strange, rough, open-air temples that partly served as sundials. We can scarcely conceive how strong was the need, among nations struggling into the agricultural state, of some means of measuring time, and thus discerning the approach of the sowing season and the coming of the harvest.

MODERN SUCCESSORS OF THE DRUIDS

Thus it perhaps came about in the New Stone Age, when a knowledge of farming was spread throughout Europe, that the men who designed and looked after the primitive sundials ranked next in importance to the royal chiefs. Indeed, in the course of time they grew so powerful that the chieftains liked to appoint members of their own families to the position of religious time-measurers. The work that the star-gazing wizards of Stonehenge probably used to perform has not lost any of its importance in the lapse of centuries. Their successors are now members of our various observatories. Were the staffs belonging to these establishments to cease work, the country to a large extent would come to a standstill. Our shipping especially would suffer. Our sailors would have to go back to the principles of navigation that were employed two thousand years ago, feeling their way from place to place by daylight and keeping to the coast. Long voyages could only be executed at great peril. Moreover, our railway system would be disorganized. A few trains could run, but only at considerable intervals, and they would have to travel by daylight and at low speed.

THE LIMITS OF ACCURACY IN KEEPING TIME

A clockmaker would not be able to save the situation. Clocks are extremely useful in their way, but it is a grave mistake to regard them as the fundamental basis of time measurement. They only deal with seconds, minutes, and hours. In the last resort we have no better means of measuring the lapse of years than the early Babylonians discovered forty centuries ago. The clear night sky, with its majestic array of stars, is still the timepiece by which we measure the duration of all things. Our clocks and watches are conveniences: the work of the astronomer is an absolute necessity of human life. In taking transit observations the time that it takes him to make a signal with his hand, as his eye watches a certain star, is the limit of accurate time measurement. One-fifteenth of a sec-



THE MYSTERY OF STONEHENGE AND ITS ASSOCIATION WITH TIME

This picture-diagram shows how the sun's rays fell on the sacrificial stone at Stonehenge on midsummer morn 4000 years ago and in the beginning of the twentieth century. Sir Norman Lockyer roughly calculated that Stonehenge was erected 1700 years B. C., by calculating the divergence of the sun's rays from the center line through the Friar's Heel Stone and the axis of the temple, the sun having shifted his apparent position, due to the tilting of the earth, which is known to be 48 seconds of an arc every century.

ond is generally reckoned to be the limit of accuracy in personal observation; for the most rapid piano player, whose rapidity of execution is the result of years of finger exercise, cannot strike a note more than twelve times a second. No doubt it is easy to build a machine that would divide a second into a hundred or more parts. Indeed, chronographs for dividing and measuring one-thousandths of a second are used in the new scientific study of motion. But no astronomer could check an instrument of this sort. The very best he can do is to keep an astronomical clock regulated to one-thirtieth of a second, and then only by means of frequent transit observations.

Time and the Telegraph

No clock tells the time exactly. It is merely a mechanism for giving an approximate measurement of the duration of things. And it can only work properly when it is regulated by the observations which an astronomer makes on the movements of the stars. So in most of the principal observatories of the world astronomical observations are made on every clear night, for the express purpose of regulating an astronomical clock with the greatest exactness. Then every day at noon a signal is sent to various parts of the country by telegraph, so that all persons who hear the signal can regulate their clock within two or three seconds. These signals also can be used to correct clocks automatically, putting them forward if they are too slow, and setting them back if they are too fast, by a simple electro-magnetic device called a "synchronizer." This is the way in which exact time is maintained in all large cities throughout the civilized world. The railway service specially owes an incalculable debt to the time-keeping astronomers who daily check, by the apparent movement of the starry sphere, all the principal clocks in the world, and thus enable railway trains to be run with a safety and exactness that no kind of clockwork could maintain.

Why a Sundial Does Not Keep True Time

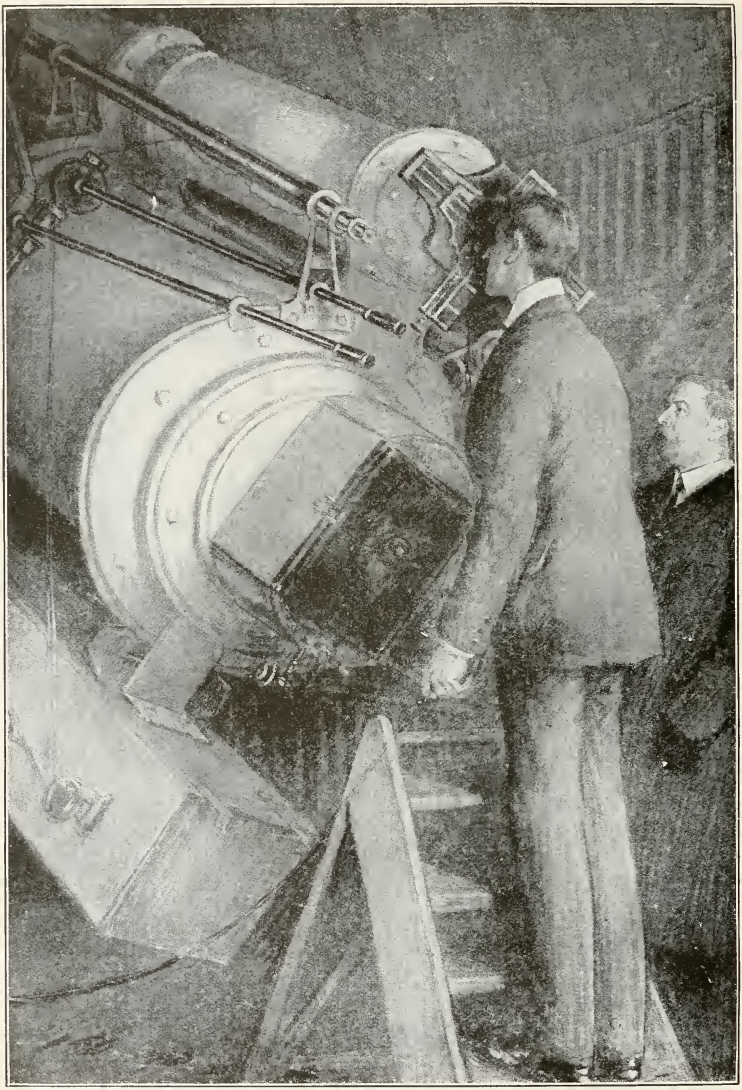
The daily revolution of the earth with regard to the sun is not uniform. As is well known, it is midday at the instant when the sun is seen at its greatest height above the horizon. But this takes place sometimes 16 minutes 18 seconds sooner, and at other times 14 minutes 28 seconds later, than twelve o'clock mean time. These curious variations are due to the fact that the earth not only has a daily revolution with regard to the sun, but that it advances at the same time along its annual path, moving with greater rapidity when it is near the sun in December than it does in July, when it is farther from the center of the solar system. The regularity of the earth's motion is also further disturbed by the attraction of the moon and some of the planets. So a sundial in the best of order is a very incorrect timekeeper; and if we had to rely entirely on observations of the sun, many of the main activities of our civilization would be sadly disordered and ill regulated.

How You May Regulate Your Clock by the Stars

On the other hand, the daily spin of the earth with regard to the fixed stars in the remote depths of space is uniform. The distance between our earth and the constellations is so immeasurably great that the variations in the position of our planet in its annual orbit are of no practical account. A star will always appear at its meridian 3 minutes 56 seconds sooner than it did on the preceding day. It is a fairly easy matter to regulate the clocks of one's household by observation of the stars; and we would commend any reader, interested in timekeeping, to measure by the stars, instead of putting up in his garden a picturesque but irregular working sundial. A transit instrument and a table giving the right ascension of the particular stars lighten the labor of observation, but neither is absolutely necessary.

As an experiment, choose a window having a southern aspect, from which

HOW TIME IS NOW MEASURED BY THE STARS



The upper tube of this telescope is used for observing the stars, by the apparent movement of which in the heavens exact time is measured. The lower, larger tube is used for solar photography.

the steeple of a church, or a tall chimney, or some other fixed point may be seen. To the side of the window attach a thin plate of brass, having a small hole in it, so that, by looking through the hole towards the edge of the steeple or other fixed point, some of the stars may be seen. Watch the progress of one of these, and at the instant it vanishes behind the fixed point make a signal to the person observing the clock, who must then note the exact time at which the star disappeared. On the following night the same star will be seen to vanish behind the same fixed object 3 minutes 56 seconds sooner. If the clock does not show this, the clock is wrong, and must be put right.

If a series of cloudy nights should then make it impossible to compare the clock with the stars, it is only necessary to multiply 3 minutes 56 seconds by the number of days that have elapsed since the last observation and record were made. Deduct the product from the hour which the clock then indicates, and this will give the time the clock ought to show. The same star can only be observed for a few weeks. For as it gains nearly one hour in the fortnight, it will at last reach the meridian in daylight, and become invisible. To continue the observation, another star must be selected and studied through the hole in the brass plate. Care must be taken that a planet is not chosen instead of a star. As is well known, most of the planets appear larger than the stars, and give a steady reflection, instead of a twinkling light.

But the surest means of distinguishing between them is to watch a star attentively for a few nights; if it changes its position with regard to the other stars, it is a wandering and misleading planet.

TIME IS MEASURED WITH A SPIDER'S THREAD

Of course, an astronomer uses more precise methods of measuring time than the rough and handy sort of observation which we have described. But we hope our description has clearly brought out the fundamental fact that all time measurement still depends entirely on the personal observation of the movement of the earth in regard to the stars. Every observatory in the world has its transit instrument, which is a fixed telescope on a stated meridian, with a spider's thread across its field. For at least four thousand years the universe has been our clock; and our fundamental clock it will remain, however much all our modern mechanisms for measuring time may be elaborated and made automatic.

The astronomers who measure our time for us are now being equipped with a cheaper and handier method of signaling the results of their observations than the telegraph wire. The invention of the electric-wave systems of wireless telegraphy is destined to have a far-reaching effect upon the general methods of keeping time; and may be actually used to operate circuits of electrically propelled clocks. All that is needed is a sensitive detector which, when affected by the electric waves from a distant transmitting station, allows the current from the local battery to act. This local current, on coming into play, moves the minute-hand of one or more dials a step forward; or rather it moves the wheel that moves the hand, each movement of the wheel affecting the mechanism regulating the position of the hour hand. Thus the elaborate works of an ordinary clock or chronometer are unnecessary. This is the contribution of the twentieth century.

How the mariner finds his location on the map

In the meantime, the extraordinary amount of science and ingenuity which has gone to the making of our mechanical timepieces deserves a brief consideration. A first-rate chronometer is one of the most interesting and useful of mechanisms. By means of it the captain of a ship is able to perform a calculation similar, but opposite, to that which astronomers make for us every night. The astronomer knows, when he undertakes a measurement of time, the exact position he occupies on the surface of the earth, and the exact position in the skies of the heavenly body that he is studying. This enables him to calculate exactly the correct time. The mariner, on the other hand, knows from his chronometer what the time is to within a fraction of the truth; and he is then able to learn, by an observation taken with an instrument he carries, his exact position on the ocean. At noon, by means of an instrument called a sextant, he measures the angle at which the sun is at its highest above the horizon; and knowing from his nautical almanac at what angle the sun is above the equator, he can quickly calculate the latitude of his ship—that is, how far north or south it is.

Why the sailor needs an accurate timepiece

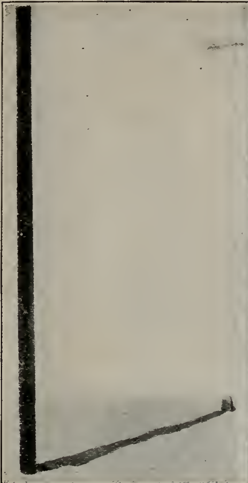
But in order to find out his longitude—that is, how far east or west he is of Greenwich—he must have a chronometer that keeps Greenwich time.

If his watch is two minutes out, he will miscalculate the position of his ship by half a degree of longitude—that is to say, by thirty geographical miles. For the earth takes two minutes to revolve that distance. In the reign of Queen Anne an Act of Parliament was passed offering a reward of £20,000 to any inventor who could find a method of telling the longitude at sea true to half a degree. A Yorkshire carpenter, John Harrison, worked at the problem for forty years, and at last won the reward by making a watch that did not lose more than two minutes in a period of several months. This will show of what incalculable value an exact means of measuring time is in ocean transport. The sun and the stars by themselves cannot help a sailor to find his time and longitude at sea, for naturally he has no fixed and settled point at which to observe them. Unless he can keep in touch with some observatory by means of electric waves, he must trust to his chronometer. Yet wireless telegraphy has made such swift and gigantic strides that, in July, 1913, wireless time-signals were transmitted over half the globe.

The Babylonian water-clock

The first mechanical device for measuring the daily lapse of time was the water-clock that was used by the Babylonians and Egyptians and other ancient nations around the Mediterranean. It consisted of a basin with a spout or tap from which water trickled into a receiving vessel. On the inside of the receiving vessel were marks from which the hours could be told by the height of the water. In the course of time this simple mechanism was greatly improved—especially by the Greeks. The receiving vessel became a long cylinder, in which a float was placed. Connected with the float was a chain passing over a pulley on a spindle, and balanced at the other end by a weight. To the pulley was fixed an hour-hand, which pointed out the hours on a dial, as the float rose on the water. The energy obtained from the rising water by means of a float or some other con-

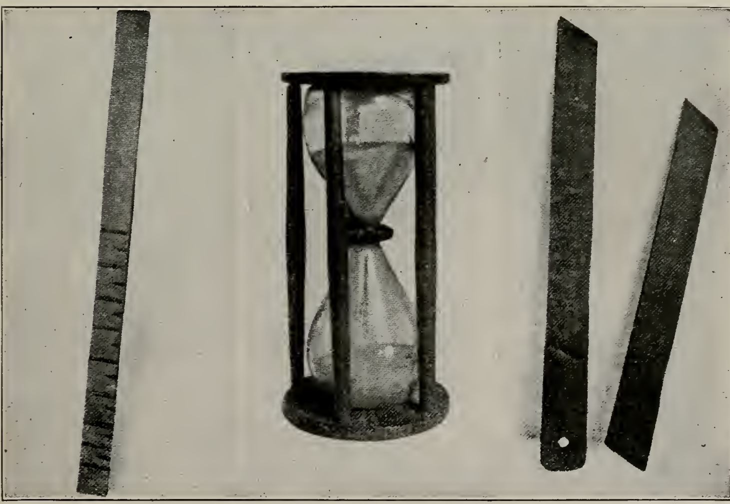
TIME RECORDERS IN CLOCKLESS AGES



This was one of the first ways in which men told the time, fixing a stick upright in the ground and marking the spot reached by the shadow. This moves round the stick, becoming shorter before noon and longer after.

At night men marked a candle in equal sections in black and white, so that each section was burned in a given time. Alfred the Great is said to have invented this way of measuring the passing of time.

Here is a simpler method of telling the time by night. A hemp rope is knotted in regular spaces, and set light to at the bottom, smoldering slowly and regularly. In Korea people still tell time in this way.



Here is a time-recorder. Every time a section of rope or candle is burned through, or an hour-glass turned, the owner cuts a notch on a stick to mark the hours of vigil passed.

This is an hour-glass, like an egg-boiler used in kitchens. One end is filled with sand, which pours through a small hole into the bottom bulb. It was once used to measure sermons!

When a master and man wished to keep a record of time for wages, two sticks were used. The servant brought his part of the stick, and the farmer compared it with his own.

trivance was sometimes used to work mechanical figures, instead of being employed to move an hour-hand over a dial. About eleven hundred years ago the King of Persia sent Charlemagne a water-clock of bronze, inlaid with gold, which was very ingeniously constructed.

The dial was composed of twelve small doors, representing the hours. Each door opened at the hour it represented, and out of it came a number of little balls, that fell one by one at equal intervals on a brass drum. The hour of the day was shown to the eye by the number of doors that were open, and the ear was informed of the time by the number of balls that fell. At twelve o'clock, a dozen miniature horsemen issued forth and closed all the doors.

The Candle-Clock and the Hour-Glass

At the time when this Oriental marvel was still being displayed in France, King Alfred made a simple clock by which, at night time, he could both write and tell the time. For it was simply a long, thick, slow-burning candle, with the hours that it took to burn marked upon it. The sand-glass that careful housewives still use in boiling eggs was also employed for some thousands of years in marking the time. The Chinese and Japanese used to make a primitive timekeeper out of a wick of flax or hemp, about two feet in length, and knotted at regular intervals. The wick was specially treated so that, when lighted, it would slowly smoulder away without flame, and the time was estimated from the unburned portion.

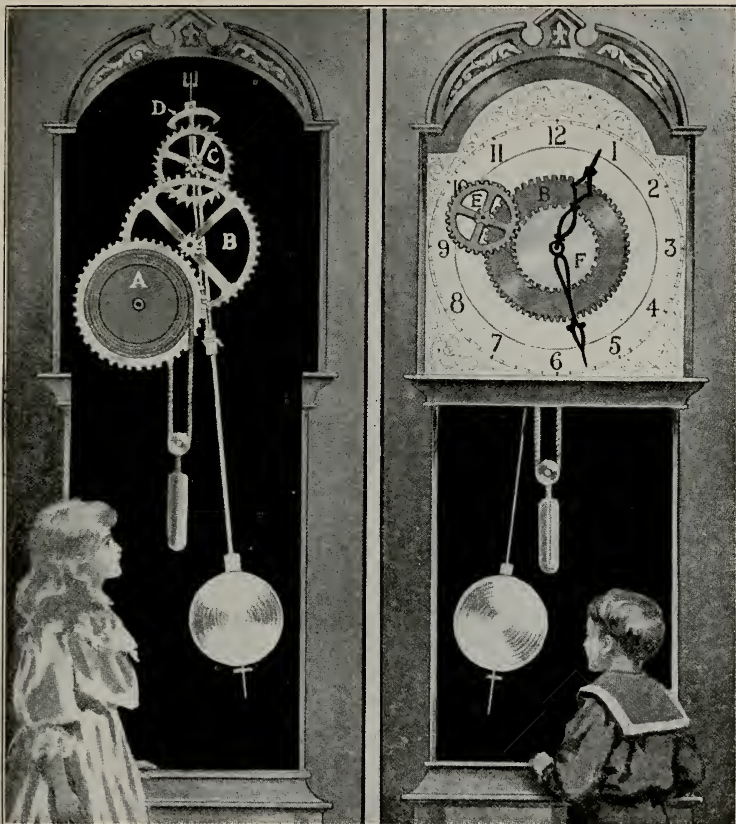
Who Invented the Weight-Clock

It is impossible to say by whom the weight-clock was invented. Even the date of its invention is unknown. A time-piece composed of an assemblage of wheels actuated by a weight was sent by Saladin of Egypt to the Emperor Frederick II of Germany, in the year 1232. And having regard to the fact that in the Dark Ages of Europe the Mohammedan races alone carried through the world the torch of science, it is very probable that they were the inventors of the first modern clocks. However this may be, weight-clocks came into use in Europe in the thirteenth century, and they were at first chiefly employed, at cathedrals and abbeys and wealthy monasteries, for indicating the hours of prayer. Few persons could then read a dial, so the hours were struck on bells by mechanical figures, known as Jacks, which excited the amazed admiration of the people. Unfortunately, the devisers of these ingenious marionette exhibitions were far more highly esteemed than the men who merely strove after exactness of time-keeping. But the clock that Peter Lightfoot made for Glastonbury Abbey in 1335 remained in working order until 1835. It is the earliest modern clock of which we have any authentic details. Most of the old weight-clocks, however, were so defective in working that about the middle of the seventeenth century the principle of the water-clock was revived and applied in a more scientific manner.

Discovery of the Law of the Pendulum

Not until the principle of the pendulum was discovered did the mechanical measurement of time become of scientific importance. But in 1580 a little boy was attending divine service in the cathedral church at Pisa, and, like many other boys, he took to staring about him instead of saying his prayers. What struck his idle curiosity was a great chandelier that had been lighted and allowed to swing until it came to rest. The boy

WHAT MAKES THE CLOCK'S WHEELS GO ROUND



This picture of the inside of a clock shows us how the wheels go round. It is not the pendulum that makes the clock go; it is either a weight or a spring. In this grandfather's clock it is a weight. The weight is on a cord which passes round a broad wheel, called a barrel, marked A in the picture. The heavy weight pulls the cord downwards, and the cord, being wound round the barrel, pulls the barrel round. The edge of this barrel has teeth which work into the teeth of another wheel, marked B, so that both wheels go round. This second wheel causes the top wheel, marked C, to go round, and so all the wheels are set to work. But if that were all, the wheels would run round too quickly, and they must be made to run slowly and regularly. At the top is a curved piece of metal with a catch at each end; it is called the escapement, and is marked D. This swings to and fro, and every time it swings, it catches the top wheel and prevents it from going round more than one tooth.

This picture shows how the wheels make the hands go round. The three wheels shown in front of the clock, marked B, E, and F, are really behind the face. B, E, and F are necessary for the hands. Wheel F goes round once every hour, and as the minute hand is fixed to it, the wheel carries the minute hand round with it. Now wheel F touches wheel E with its edge, making it go round also. E is a double wheel, having near the center a small wheel fixed to it with only six teeth; it is really on the other side of wheel E, but is shown in the picture in front for clearness. Each tooth in it fits into a tooth in wheel B, thus making that wheel go round. As wheel E goes round once in an hour, the six teeth in its center carry round one-twelfth of wheel B, which has seventy-two teeth. The hour hand is fixed to wheel B, so while F is going once round, it makes wheel E drive B one-twelfth of its journey. Thus wheel F, with the minute hand, turns twelve times while wheel B, with the hour hand, turns once expected that as the swing of the big lamp grew smaller, it would move more quickly over the shorter space. But it seemed to him that the time it took to swing over decreasing distances was uniform. He wanted some way of measuring the duration of the lessening movement; and, with a flash of genius, he thought of counting his own pulse-beats, and measuring the time the chandelier took to swing first over a large space and then over a small space. To his surprise, he found that all the varying swings of the big lighted lamp were measured by exactly the same number of pulse-beats.

When he went home, he tied a weight to a string and set it swinging from a beam. Again he found that no matter whether the arc of the swing was large or small, the time taken in covering the various distances was equal. Thus did Galileo in his boyhood discover that the swing of a pendulum is equal-timed. As a matter of fact, this is true only when the arc of vibration is small.

On the other hand, the weight of a pendulum has no influence upon the time of its vibration. For the effect is produced by gravity, as Galileo went on to show, and the time that bodies take to fall to the ground under the action of this force is independent of the weight. A swinging or falling weight of two pounds is only equivalent to two pound-weights swinging or falling side by side.

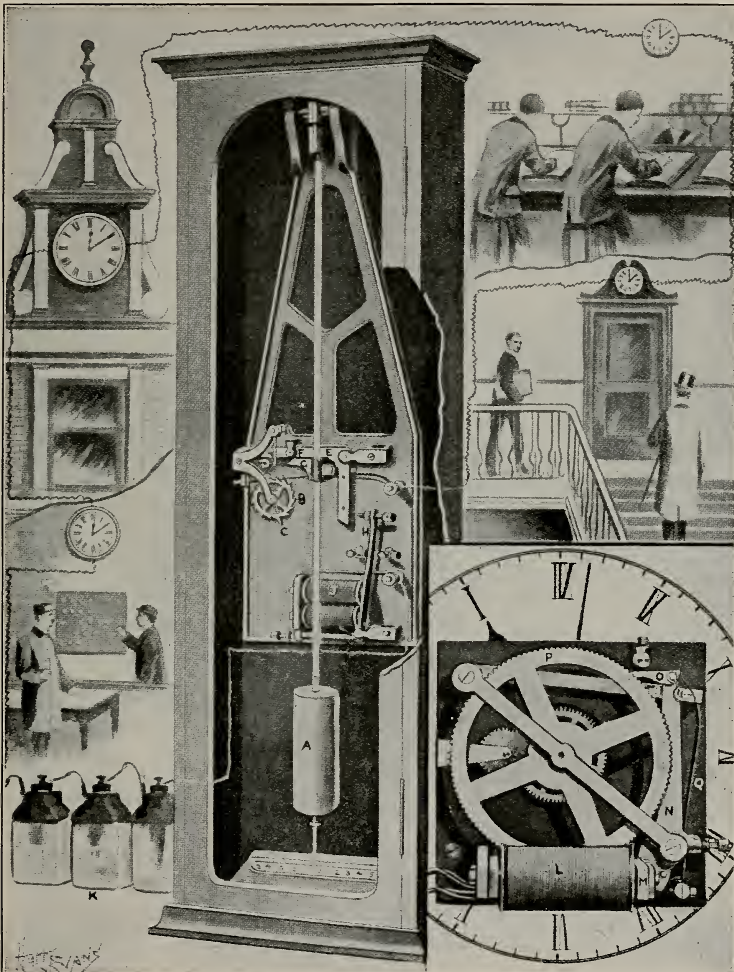
The discovery of the peculiar property of the pendulum gave the makers of weight-clocks the regulating instrument for which they had vainly searched for centuries. A clock consists of two principal parts. There is first a train of toothed wheels, which transmits to a definite point the motive force produced by a weight or spring. But as the motive force would expend itself with wasteful rapidity in setting the train of wheels going at a furious rate, a mechanism is necessary for regulating the expenditure of the motive force with the requisite uniformity and slowness. So the second main part of a clock consists of the pendulum or time-governing device, and the escapement, by means of which the pendulum controls the speed of going.

Escapement Mechanism of Clocks and Watches

It is difficult to describe an escapement mechanism in words, though it is simple in action. But we must at least attempt an explanation of Galileo's contrivance. For, though it was unsuccessful at the time, it contained the germ of the chronometer-escapement and free pendulum which are likely to be the escapement of the future. Galileo made a wheel with a number of pins sticking out, not from its edge, but from its side. Sideways, near the top of the wheel, a ratchet engaged with the pins, and at the same time was connected with the pendulum beneath by a small downward projecting arm. Touching this arm at times was another straight arm, running sideways from the top of the pendulum rod, and moving with it. This pendulum arm extended partly over the side of the wheel, in such a way that it came into contact with one of the pins.

The wheel, of course, went round by the motive force of a weight or spring transmitted through a train of wheels. But as the ratchet engaged with the pins, the entire motion was stopped until the pendulum came swinging back at the end of its beat. The pendulum arm then struck the lower projecting arm of the ratchet, and raised the ratchet from the pin with which it was engaged. So the wheel then went round, and one of its lower

MANY CLOCKS WORKED BY ONE PENDULUM



HOW AN ELECTRICALLY DRIVEN PENDULUM TURNS THE HANDS OF NUMEROUS DISTANT DIALS

By the aid of the electric current all the clocks in a large factory or even a town can today be controlled by a single pendulum. This diagram shows the principle of the synchronome system. The clock consists of the pendulum (A) alone, which pulls round the wheel (B) once every half-minute. The vane (C) then withdraws the catch (D), and allows the gravity lever (E) to fall. The little roller (F) presses the pendulum aside by running down the bracket (G) mounted upon the pendulum. The lower arm of the gravity lever (E) then meets the contact screw in the end of the armature (H), thereby closing the circuit of the electro-magnet (J), which allows the current from the battery (K) to pass through the dials all over the building. These dials are advanced half a minute whilst the electro-magnet (J) attracts the armature (H) and throws the gravity lever (E) up on to its catch again. The clock-faces have no "works" behind them, only one wheel and a magnet, shown on the right. The electro-magnet (L) receives the half-minute impulses, so attracting the armature (M), and by means of the lever (N) enabling the click (O) to pick up another tooth of the wheel (P). The spring (Q) then propels the wheel (P), and the minute-hand attached to it, one half-minute pins struck against the arm of the pendulum and thus gave the pendulum its forward stroke. But in making this stroke the pendulum lowered its side-arm. This enabled the projecting arm of the ratchet to drop freely, with the result that the ratchet itself engaged with the next pin on the wheel, and again stopped the movement of the clock till the arm of the pendulum again swung back.

As a matter of fact, this arrangement did not work well, and the use of the pendulum had to wait until Huyghens investigated its mathematics and enunciated the laws governing oscillatory bodies, in 1673. But almost another century elapsed before the escapement mechanism of a watch was converted into a good regulator by the great George Graham, whose famous dead-beat escapement is still used in many a high-class clock today.

It was impossible to take a pendulum-clock to sea and suspend it so as to avoid disturbing its motion by the rocking of the ship. The ship's chronometer is a large watch, about six inches in diameter, mounted on gymbals, in a mahogany box.

A modern chronometer escapement consists of a toothed wheel, against which two levers work. A delicate spring at the top of one lever comes at times into contact with a little projection at the bottom of the other lever, so the escapement-wheel is alternately held and released by the interaction of the two levers.

Electric world-clock

The electric world-clock into which the Eiffel Tower in Paris has been transformed excites the liveliest interest in western Europe, where it is easy for anybody, with the aid of very simple wireless telegraph apparatus, to receive the time signals radiated at fixed hours over sea and land.

Eiffel tower makes fine station for wireless signals

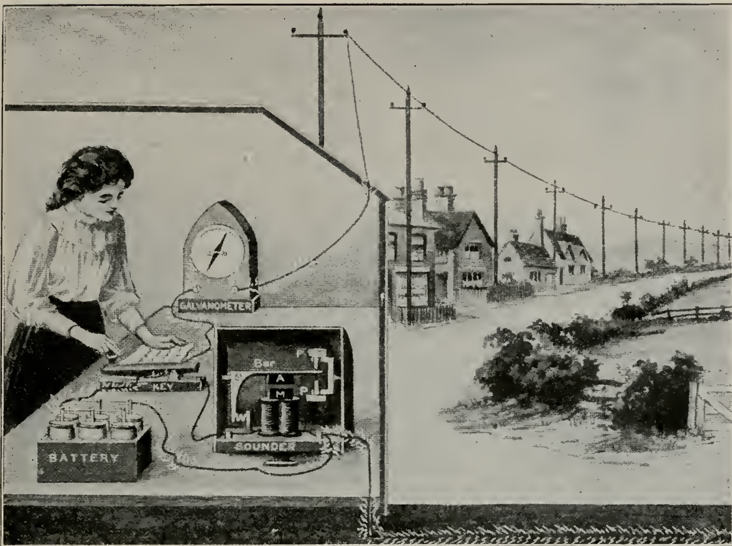
The Eiffel Tower has been chosen for this purpose because its immense height, nearly a thousand feet, gives it a distinct advantage as a sending station for wireless signals. But at the very moment when this finger of steel pointing skyward out of the heart of Paris becomes, as it were, a clock hand for the whole planet, the meridian of Paris is officially abandoned.

The order has gone forth that henceforth the *Connaissance des Temps*, the famous French astronomical almanac, shall have its calculations based on the meridian of Greenwich—the prime meridian that all the civilized world now recognizes.

The world's standard wireless telegraph timepiece does not keep step with the hours as they flit across the world's standard meridian of time, and an allowance for difference of longitude has to be made by everybody who receives the signals from the Eiffel Tower, if he wishes to know what the true world-time is. What he gets is Paris time.

The observatory of Paris automatically, by an electric clock, transmits to the Eiffel Tower the time signals that are radiated over the globe, and these time signals are regulated by the passage of stars across the meridian of Paris, and not that of Greenwich. But Paris is situated 2 degrees 29 minutes and 15 seconds of longitude west of Greenwich, corresponding to a difference of 9 minutes and 21 seconds of time, which must be either added to or subtracted from the indications of the signals in order that standard world-time may be obtained.

If the observer is west of Paris he must add the extra time to get the hour at Greenwich, and if he is east he must subtract.



THE STARTING OF THE TELEGRAM

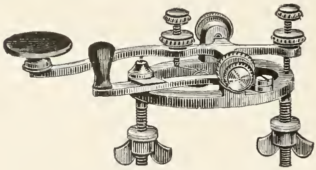
In the left corner we see the interior of a telegraph office. Outside we see the wires running across country. The girl is sending a telegram to the office shown on another page hundreds of miles away. Each time she presses down the key with her right hand, a current runs from the battery, through the key, which connects the twe wires, through the galvanometer, and out over the wires to the far-away town.

HOW WE SEND A TELEGRAM

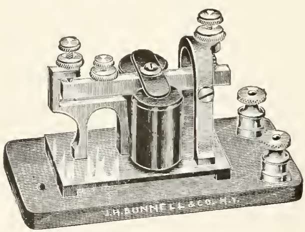
NOBODY can say what electricity really is. It is not matter. It cannot be seen, though its effects can; it cannot be smelled or tasted. We call it a fluid because we cannot give it a better name. But though we do not know what it is, we know how to bring it into use, how to create or excite it, how to harness it and make it our most marvelous and obedient servant; and one of the chief wonders electricity performs for us takes place after we hand a telegram across the counter of a telegraph office. A telegram is one of the familiar things in our lives which are really so wonderful that no man can quite understand them.

If we wish to send a telegram, say from Chicago to New Orleans, we must have in the telegraph office a battery from which we can send electricity along wires. The wires coil round a piece of iron, and so long as the current of electricity is passing through the coil the iron acts as a magnet, an electro-magnet as it is called, and draws other metal to it. The moment the current ceases, the iron is no longer a magnet. We see a picture of this electro-magnet and battery in the above picture. When we send the electricity through this coil, we call it magnetizing the coil. The current flies swiftly along the wire, and while it is going the circuit is said to be closed. When the current ceases, the circuit is broken. Now we hand our telegram for New Orleans to the telegraph operator.

Before him there is a little lever with a knob at the end. This lever is called a key. While that key is at rest, the circuit is broken. The moment he presses it down, the circuit is closed, and the current races along the telegraph wire. He taps away at his key and the message flies over the wires to be written down at the New Orleans telegraph office. How is it done? New Orleans is the receiving end. Well, there, at the end of the wire, they have an electromagnet made as we have seen, of wire and iron. A current comes from Chicago. It enters the office by the wire. It passes through the coil and makes the iron magnetic. The magnet attracts towards itself a little metal bar working on a lever, and every time this bar comes down towards the magnet, the end of it taps upon a small screw; then when it goes up again it taps on another screw. Each tap that it makes corresponds with something that the clerk in Chicago has done at his end of the wire.

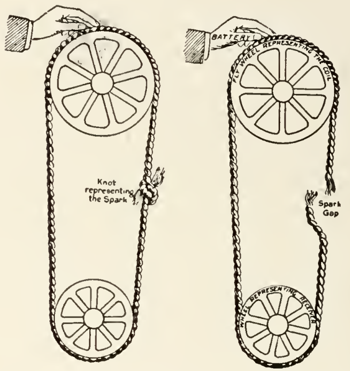


A telegraph key used to send telegrams



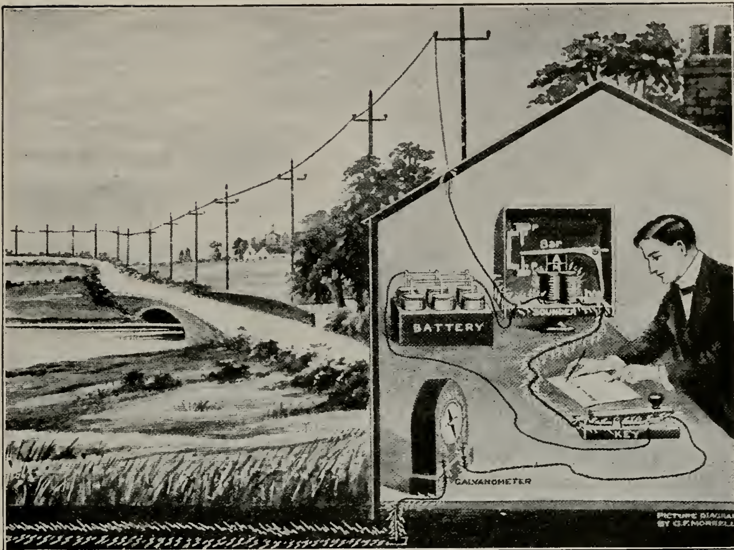
A sounder used to receive messages

The Chicago clerk, as we have seen, presses down a key. That key, when at rest, has its knob raised in the air. There is a wire attached to the key. Now, when the key is pressed down, its under side touches another wire. The pressing down of the key joins these two wires together. That closes the circuit. The joining of the two wires instantly causes a current of electricity to flow from the Chicago battery over the wire to New Orleans. The instant that the key is allowed to rise from the wire underneath it, the current is stopped, and the circuit is broken. While the current is flowing, the coil and iron at New Orleans become a magnet, that draws towards itself the small metal bar.



This diagram explains the uses of the battery, coil, and wires in the sending of a telegram. The hand stands for the battery, which provides the energy. The big wheel represents the coil, which regulates the electric current to flow as we want it. The rope represents the flow of the current, conveying the energy to the small wheel, which stands for the receiving end. The knot is for the electric spark, which ties the ends of the rope, or current, together, as it were. When the knot is tied, the circuit is closed. When the knot is untied, the circuit is broken. It is the rapid tying and breaking of the spark-knot that produces the electric waves

Clever men thought out a way of making this of use. They arranged that certain pressures by the sending key should stand for certain letters. We have only to agree once for all that a certain sign shall stand for a



WHERE AND HOW A TELEGRAM IS RECEIVED

We are sending this telegram by the simple single-wire system, so the clerk has to write down the dots and dashes as they sound. Each shock pulls down the iron marked A, causing the bar to strike the pegs P P and sound the "dots" and "dashes." From the girl, the current passes along the wires, then back through the instrument, into the earth. When the man telegraphs, the current goes into the earth and back along the wires to the girl.

certain thing, and then we know what it means. And that is how we got the telegraph's A, B, C. A very short pressure of the key in Chicago gives two taps at New Orleans, one very quickly after the other, and a longer pressure gives two taps, but with a longer interval between them. These double tappings, one with a short interval between the taps, and the other with a longer pause, correspond with the dots and dashes of the Morse alphabet.

When we send our telegram from Chicago to New Orleans, the telegraph operator turns the letters which we have written into telegraphic letters by tapping away at his key in the manner agreed upon. Each tap is registered at New Orleans instantly it is made. With each pressure upon the key the circuit is closed, and the current flies for a certain length of time, signifying a sign which means part of a letter. Each time the key is at rest in its ordinary position, the current ceases to flow.

But there is a limit to the speed at which a man can tap his key. If he is very skilful and strong he may be able to send as many as forty words a minute. More likely he will not be able to send more than twenty-five. That is not quick enough when the message which he sends, instead of being a little telegram from one of ourselves, is a long one of thousands of words—a speech, or the account of some great event. For this, another system is used. A message of twelve hundred words, for instance, would be divided among, say ten clerks, each of whom sits before a machine that punches holes in a ribbon of paper, the holes corresponding to the letters of the Morse alphabet. Each clerk punches 120 words of the message, at the rate of 25 words a minute, so that, when the work is divided in this way, the whole message is punched out on the tape, or ribbon, in about five minutes. The ribbon is then run through an elaborate telegraph instrument, called an automatic transmitter, because it works itself. The ribbon runs through in such a manner that the circuit is closed at each hole in the paper representing a dot or a dash, and the current flows along the line, to be registered at the other end, in ink, upon a tape. By this machine, messages can be sent at the rate of 400 words a minute. The recording of the dots and dashes upon a tape at the receiving end is necessary, because no clerk could write out the message at the rapid rate at which it is received. The writing out is done from the printed dots and dashes on the receiving tape.

We do not find this recording instrument in small telegraph offices. The instrument which is used in railway signal-boxes and stations is what we call the needle instrument. There we find a little dial, in front of which a needle works to right or left, according as dots or dashes are meant. By watching this, the operator can take a message quite easily. But as the needle moves to right and left it strikes upon two little bars of metal, each different from the other, so that they give out different sounds, and by listening, without watching, the clerk is soon able to read the message by sound, just as the clerks in the telegraph offices do with their improved instruments.

Perhaps the greatest wonder of the telegraph line is the fact that several messages can be sent at the same time. Two messages can be traveling over one wire at the same time from Chicago to New Orleans, while two others are coming at the same time over the same wire from New Orleans to Chicago. This is done by arranging different strengths of current. The messages that are traveling together from the south to the north are each sent by a current which is of different strength from that of the others, and the same is the case with those coming from the north. Each current goes to a receiver, which takes a current of particular strength.

If we have relatives away over the sea to whom we may wish to telegraph, we can reach them by a message carried by electricity under the sea. Cables run under the Atlantic and Pacific Oceans, under the Mediterranean Sea, the Black Sea, the Indian Ocean, the North Sea, the English Channel, and so forth. There are about 250,000 miles of these submarine cables in use, so that we can exchange messages with England, Panama, Australia, New Zealand, India, China, and every other civilized country. The principle is the same as in the land telegraph, but the wires are different, and the rate of telegraphing is slower, as the current passing through these long wires is necessarily weaker, which makes the recording of the messages slower.

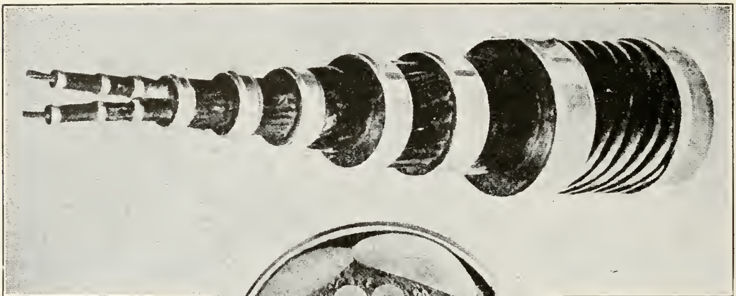
If the ordinary telegraph wires were used, the current would run off into the sea and be lost. So the wires have to be encased in gutta-percha, and bound round with tape and yarn, and brass, and tarred hemp, and over all are wound coils of stout wire, to protect the cable from the sea, and the rocks at the bottom of the ocean. For long distances, only one wire is placed inside the cable, but for shorter ones many can be used. More than one message can be sent over the cable at the same time.

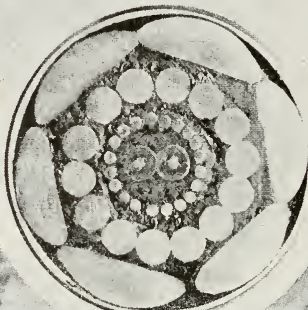
THE VALLEYS, MOUNTAINS AND PLAINS AT THE BOTTOM OF THE ATLANTIC OCEAN

If all the water in the Atlantic Ocean could be drained away, the ocean-bed would look like some great stretch of country with deep valleys and mighty mountains. These mountains would be the islands that now peep only above the waters. Stretching across the new country we should see the many cables that enable the Old World and the New to talk together.

THE ELECTRIC WIRE THAT RUNS UNDER THE SEA

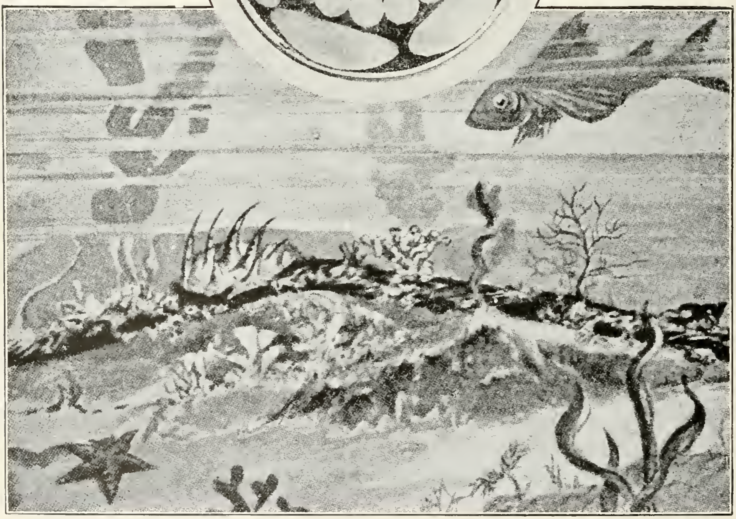
One of the most wonderful things in the world is the way in which a thought can be flashed across the earth quicker than a messenger can carry a letter across a town. Every day messages are sent under the sea by means of electric cables lying along the ocean-bed. The question answered on another page deals with this great achievement of man and the pictures in the following pages show us how the cables are laid.





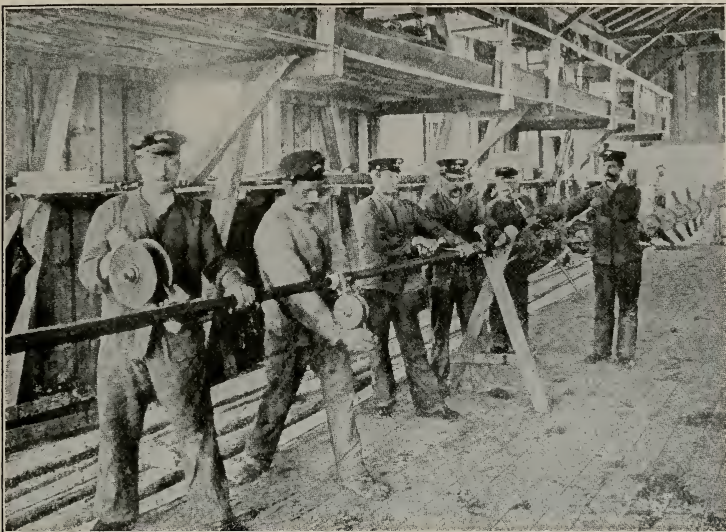
When we telegraph abroad, electricity carries our message through a thin wire under the sea. The wire would snap if it were not protected by coats of paper, india-rubber, hemp, lead, and steel. A cable is always thickest at its shore end.

In the top picture we can see a piece of cable with the different layers cut away a little to show them clearly It is the two thin wires at one end that carry the message. The picture in a circle shows a section cut across the same cable.

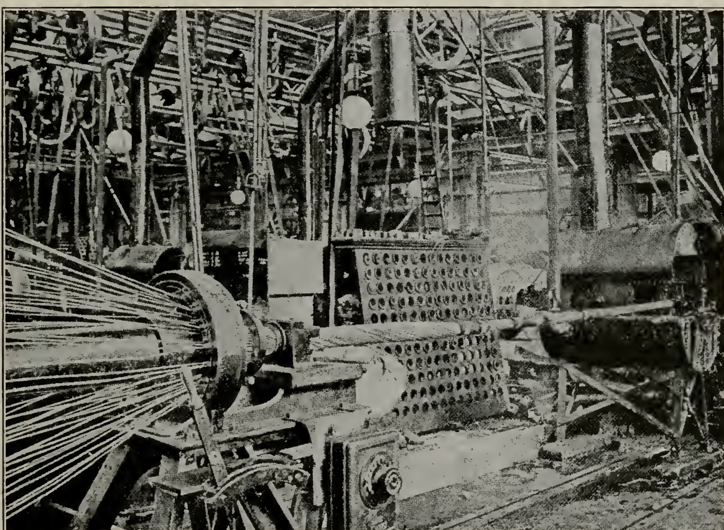


Marine plants and sea animals fasten and grow upon the cable at the bottom of the sea, as may be seen in this picture. Sometimes a cable is pulled to the surface with a large piece of coral growing all round it, or some big fish is mixed up with it. These were the greatest difficulties that the early layers of deep-sea cables had to fight against and learn how to overcome. Several years ago, something went wrong with a cable in the sea near Valparaiso, in South America. When it was hauled to the surface of the ocean, there was a dead whale with the cable coiled round its body. Such incidents are not uncommon, hence the need for great strength in the cable.

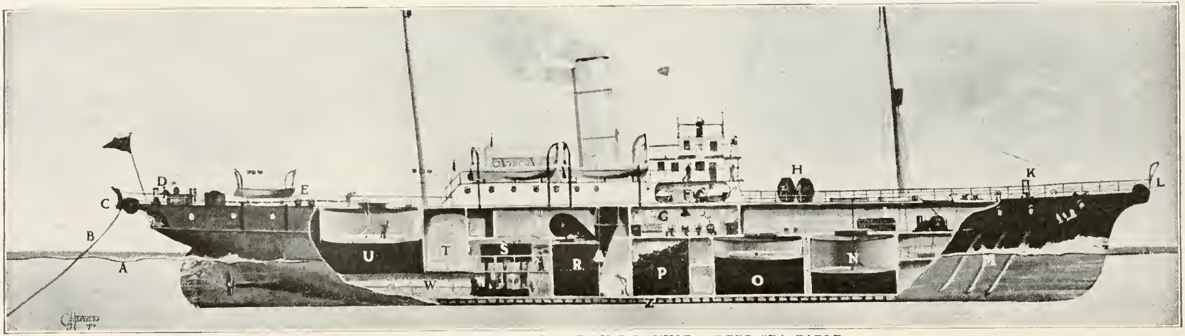
MAKING THE ELECTRIC CABLE FOR THE OCEAN BED



Here we see a submarine cable in the course of being made. The men are putting on one of the many coats that cov.. the metal and protect it from damage, and prevent the electricity from escaping under the sea.

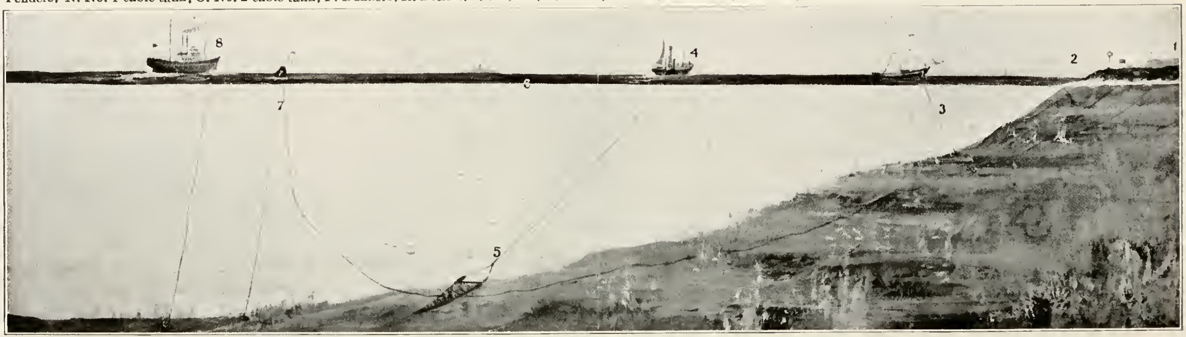


In this picture we see how the cable, after it is covered with gutta-percha, is bound round with wire. Every detail of the work must be most carefully performed, for if there was any flaw the cable would be useless.



SECTIONAL VIEW OF A CABLE SHIP LAYING A DEEP-SEA CABLE

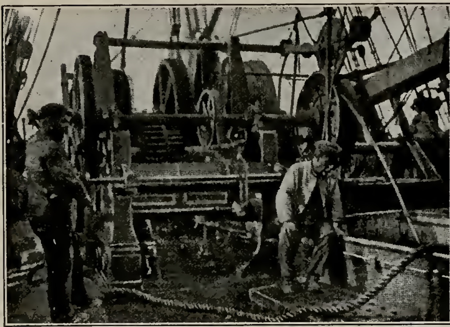
A. Water line; B. Cable; C. Stern sheave; D. Dynamometer; E Retarding wheels; F Testing-Room; G. Dining-saloon; H. Buoys; I. Grapnel rope; K. Dynamometer; L. Bow sheave; M. Fenders; N. No. 1 cable tank; O. No. 2 cable tank; P. Bunkers; R. Boilers; S. Engines; T. Stores; U. No 3 cable tank; W. Shaft; Z. double bottom.



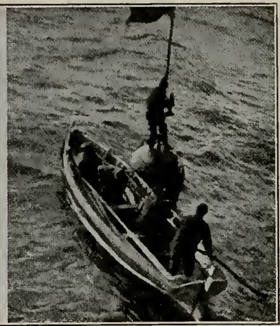
THREE COMMON CAUSES OF SUBMARINE CABLE BREAKAGE BY TRAWL, TIDE, AND ANCHOR

1. Cable house; 2. Waves and currents; 3. Ships' anchors and 4 and 5. Trawls, are constantly doing damage; 6. Water line· 7 End of cable temporarily attached to mark buoy; 8. Using grapnel to find broken cable

HOW THE CABLE IS JOINED TOGETHER AT SEA



After fixing the cable ashore, the ship steams away, and the cable passes over a drum or grooved wheel, as seen here, and then over the side of the ship. A vessel cannot carry a very long cable all at once, so it has to return to land for a second instalment.

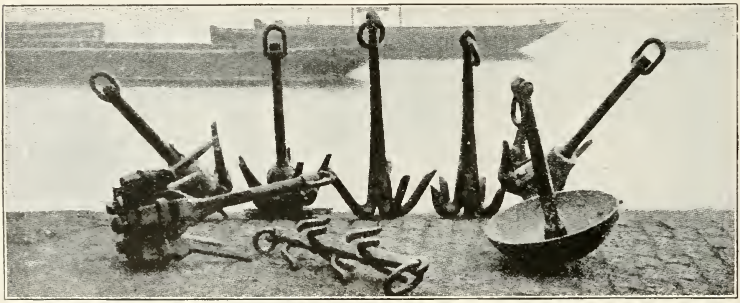


A buoy is put to mark the place where the end of the cable is let down. When the ship returns, the end is hauled up and joined to the new cable, as seen here.

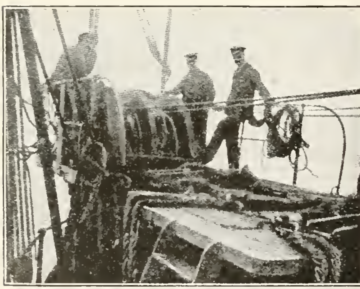
When the cable has been laid right across the ocean, the end must be taken ashore to be fixed in the cable station, just in the same way as we saw it done at the beginning of the laying operation. Here the cable is seen supported on barrels from the ship to the shore, and the shore part is being placed in a trench.

HOW A CABLE IS LOWERED AND RAISED

The cable is now laid under the sea, except where part is still held by ropes from the ship. The rope holding the cable is now laid across a wooden block, and a man with an axe cuts the rope. Then the cable sinks to the bottom of the sea, and as long as it carries the messages properly it is allowed to remain undisturbed.



If the cable does not work properly, it must be raised to find what is wrong. In this picture we see a collection of the curious grapnels, or grappling-irons, used for catching hold of a cable at the bottom of the sea



These men are using grapnels. They can tell when the cable has been caught by the grappling-iron, owing to the jerk of the rope or chain that holds the grapnel.

When a cable is hauled up, a man is swung over the side of the ship to fasten a rope to it, as shown here, and then the cable is pulled on board for repairs.

The speed at which cablegrams can travel is very great, though we have not yet the instruments to receive the messages quickly. A signal has been sent 8000 miles under water in a single second. But we could not send a long message at this rate. As it costs twenty-five cents a word to cable across the Atlantic, codes are used by which one word may mean a dozen or more words. By this means time and money are saved. Once an English firm cabled to their manager in Victoria, British Columbia, and received the answer in a minute and a half. The distance there and back is 18,000 miles.

Not many years ago at an electrical exhibition in Chicago, a message was sent from a room, through the United States to Canada, from Canada to London, from London to Portugal, Spain, Egypt, India, and Japan. It came back by the same route, and was received in the same room from which it had started, but at another instrument. It had been round the world in fifty minutes.

WIRELESS TELEGRAPHY

WHEN we read of the various useful inventions of such great men as Edison and Bell and Marconi we are sometimes led to think that all great discoveries in science are made by means of experimentation alone. This, however, is not true. Before one can begin to experiment with any hope of producing a useful invention he must first understand those laws of nature which underlie the problem he is trying in a practical way to solve. For example, much valuable time and many thousands of dollars have been spent in a vain attempt to produce perpetual motion. Had those experimenters who have worked on this impossible problem fully understood the law of the conservation of energy all this time and money might have been saved.

Not only is it necessary to understand the fundamental laws but it is the work of some one to discover these laws and principles in the first place. In other words, before we can apply a principle to produce or invent a useful article or device we must have the principle to apply.

Now new facts or truths in nature are often discovered by men who do very little if any experimenting. Such a man was James Clerk-Maxwell, the late renowned English physicist and mathematician. England has contributed many illustrious men in the development of the world's scientific history, but not even Newton surpasses this famous scientist in real genius and remarkable insight into the mysteries of nature.

Length of ether waves

Professor Maxwell discovered by the aid of mathematical reasoning that there exist in the ether waves of very much greater length than those concerning which we read under the subject of heat and light. He maintained that these long ether waves travel with the same speed as light. In fact, it was the thought of this great theoretical investigator that these very long waves constitute what we know as one form of an electric current. Indeed, he went so far as to contend that light and certain forms of electrical disturbances are practically one and the same thing, both being waves in the ether, the only difference being in the length of the waves. Now this was a remarkable theory, and the interesting and singular thing about it all is that Maxwell himself did not live to see his theory put to a practical test.

By the aid of higher mathematics this college professor discovered these wonderful truths of nature, but it was left for other scientists who came later to confirm his conclusions and extend them into practical fields.

Not long after Maxwell's death a young German high school physics teacher actually discovered these electric magnetic waves that the great Englishman had predicted. It was Heinrich Rudolf Hertz who made this great discovery, and these long ether waves are called Hertzian waves in his honor.

Hertz very carefully studied the behavior of these waves and found that they obey all the laws of light waves and travel with the same velocity, viz., 186,000 miles per second. The retina of the eye is not sensitive to these long ether waves, but Hertz was able to detect their existence by means of very simple apparatus. We learned in our study about heat that certain ether waves cause the molecules of bodies to vibrate more rapidly. Now these long ether waves which we are now considering, and which hereafter we shall call electric waves, produced a somewhat different effect on matter, particularly on metallic substances.

For example, if a copper wire is in a region traversed by such waves there will be set up in that wire an electric current, which current will rush back and forth from one end of the wire to another.

If our metallic conductor is in the form of a circle and the ends separated by only a very small space, tiny sparks will jump across this gap whenever the electric current is set up in the wire as a result of the presence of electric waves. Hertz used a device of this kind to find out a great many important and useful facts about these remarkable waves.

How waves are set in motion

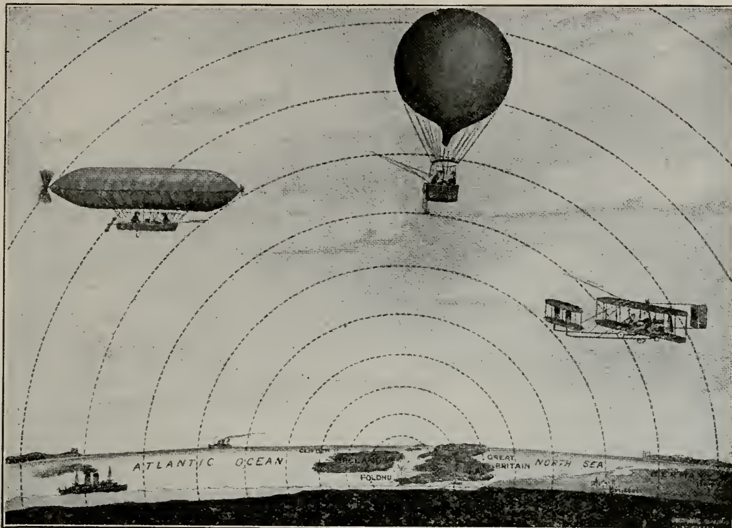
But how are such waves started or set in motion? When an alternating current is oscillating back and forth in a wire it disturbs the ether in and about it just as the vibrating electrons of an incandescent body set up waves in the surrounding medium. Such ether waves are known as electromagnetic waves, or, more briefly, electric waves.

When considering the method of producing electric waves it is well to remember that the ordinary commercial alternating current which flows along the wires in our homes and gives us light is of a comparatively low frequency, ranging from 25 oscillations per second to 135, the most common being 60 cycles. It has been found that currents of much higher frequency than the above are most effective in setting up electric waves. Currents having from one hundred thousand to a million oscillations per second are employed in producing strong electric waves. Now the length of these ether waves generated by a high frequency current depends upon the frequency of that current. The greater the frequency the shorter the waves; the lower the frequency the longer are the resulting waves. Hertzian waves range from a few feet to several miles in length.

High frequency currents

Further, it should also be understood that the form and general arrangement of the metallic conductor carrying these high frequency currents have a great deal to do with their effectiveness in radiating electric waves. It was the discovery of this very important fact by Dr. Marconi and others that has made it possible to signal through space without wires. Marconi learned by experiment that a vertical wire, or system of wires, having the lower end connected to

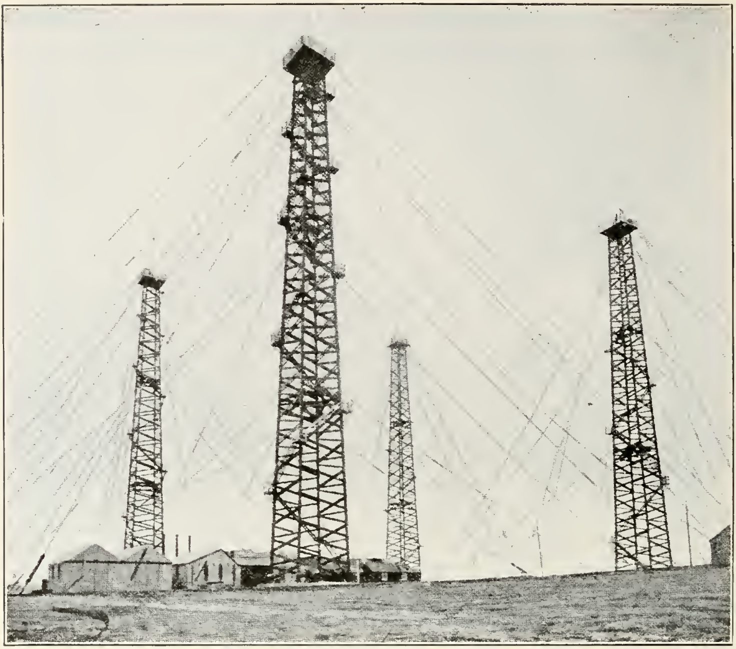
WORDS TRAVEL EVERYWHERE ON ELECTRIC WAVES



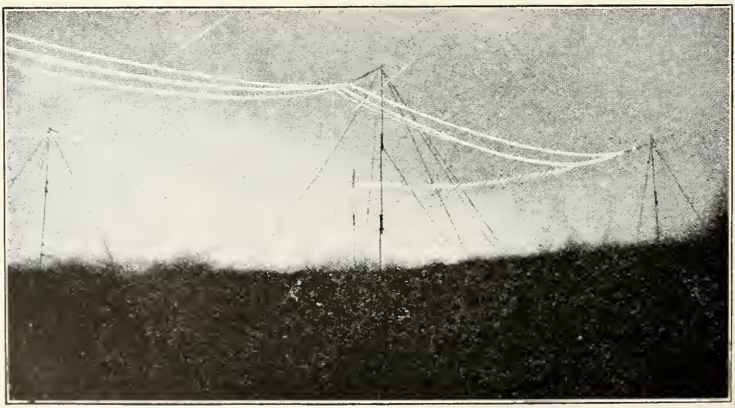
This picture shows us in a diagram the wonderful way in which the electric shocks travel through the ether. The wireless waves radiate in all directions, outwards and upwards, so that in less than one-sixtieth of a second a dot of the message, shown here as being sent from Poldhu, could be received in London, Norway, Berlin, America, or on any ship sailing on the Atlantic Ocean. It is to prevent everyone receiving everyone else's messages that the instruments are tuned. The message could also be received in airship, aeroplane, or balloon at thousands of miles above the clouds if men could get there. It is also believed that they descend into the earth.

This picture shows us, in another way, what we see above—how the wireless waves radiate, expanding evenly in true circles. The boy has thrown a stone into the river, and the waves flow outwards, getting fainter and fainter the farther they get from the spot where the shock occurred. The wireless waves are waves in the ether very like these water-waves, with this difference, that while the ripples of water travel only in a horizontal direction all round, and at a slow rate, the wireless waves travel at a very rapid pace, and in all directions. A better illustration of how these electric waves travel is provided by the light from a lamp or candle. The light-waves move from the flame in every direction, and the wireless waves travel through the world in exactly the same way from the center at which the message is sent off.

WIRELESS STATIONS ON DUTY DAY AND NIGHT



The structures, with the wires at the top, are built high so that the electric waves, when starting across the sea, may not meet with obstructions. On striking the ocean they leap from crest to crest of the sea-waves.



This picture gives us a glimpse of a wireless telegraphy station by night. Whether it be light or dark, the wonderful waves created by the power of electricity speed on their way across the waters. Receiving instruments are ready to record their message, and the words fly, in dots and dashes, speedy as light, and as noiseless.

the earth radiates electric waves much more efficiently than any other arrangement. By utilizing an oscillator of this character Marconi was able to signal over a distance of several miles where previous to this discovery the waves could not be detected beyond a few feet.

Let us now direct our attention to the practical methods used to produce these high frequency currents in the vertical wire or oscillator as it is sometimes called, and to the modern means employed to detect electric waves at great distances from the sending station. Improvements in the apparatus used for practical wireless telegraphy are being made with such astonishing rapidity that the past few years have witnessed almost a complete change in radio equipment. Because of this rapid development and in view of the changes that are certain to come in the immediate future, it will be well to confine our attention to a brief description of the latest forms of apparatus used to transmit messages over thousands of miles of space.

The Wireless Instruments

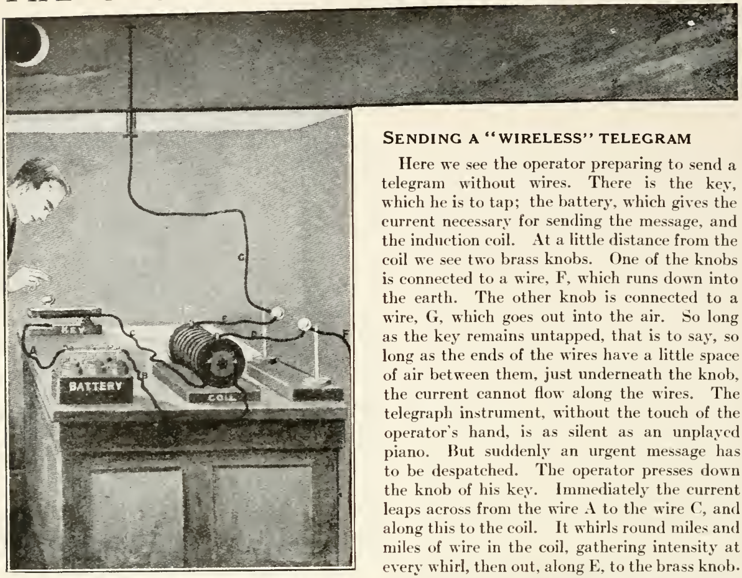
By the use of an instrument called a transmitter, these electric waves can be sent bounding forth through the air in all directions. By making a receiver in tune with the transmitter, we can make that receiver take a message. To receive the message an instrument called a coherer is used. A coherer is a glass tube, sealed at both ends with metal, and filled with nickel and silver filings. When an electric wave comes along, it passes through this tube. It magnetizes the metal filings, and causes them to draw close together—to cohere, and to close the circuit. The wave is quickly gone, the filings are no longer magnetized, and the circuit is then broken again.

The coherer receives a light tap from a little automatic tapper, and the filings fall apart again instantly, to be as they were before, ready to receive the next electric wave. When the metal filings come together and close the circuit, they operate a bell or sounder, and the message which they tick is read and written down, ready to be sent to the person for whom it is intended.

Thus we send a message thousands of miles across the ocean without the help of wires. Here again the rate is slow. Cablegrams run off at the rate of fifty words a minute, but the wireless telegrams go at the rate of only twenty-five words a minute. Some day, of course, this pace will be greatly improved. Wireless telegraphy is one of the great gifts that inventors have given to mankind, and we cannot yet realize the importance of it to the world. The pictures on these pages show how wonderful is the power that wireless telegraphy gives us to speak across the sea, and sometime ago there happened a wonderful thing, showing how the power of telegraphy without wires may save great disasters at sea. Let us read the story of how a man tapping away into space saved a thousand lives.

Let us picture to ourselves an immense liner moving slowly from its berth. The wharf is crowded with people waving their hands and fluttering handkerchiefs. From the side of the ship, on all the decks, leans a multitude of passengers waving farewell. The space between these two crowds slowly widens. Between ship and shore flows an increasing space of troubled water. The faces of people become indistinct. The sounds die away. Then the engines get to work, and the great ship moves forward, and draws impressively to sea.

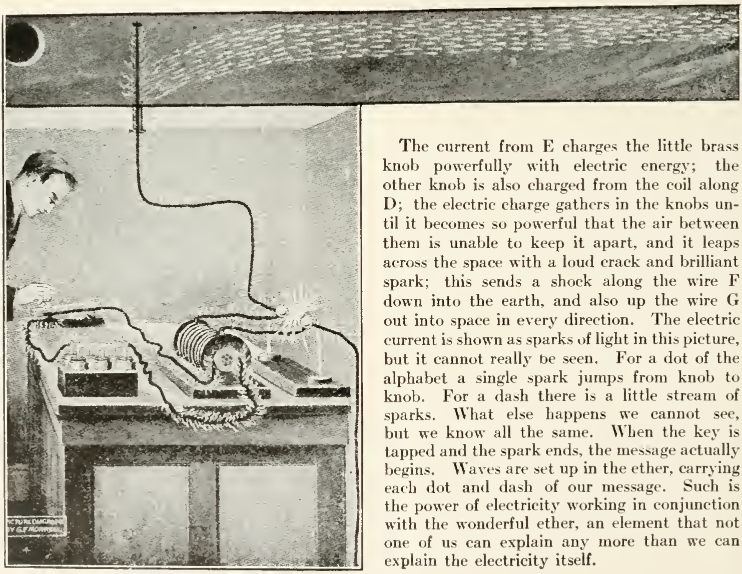
The passengers hurry to their cabins. They see that everything is comfort-



The operator ready to send a message

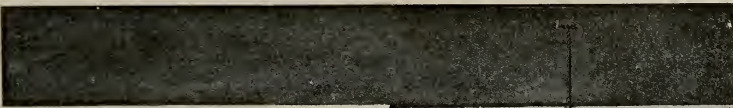
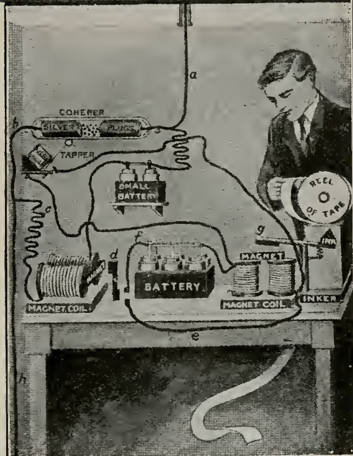
SENDING A "WIRELESS" TELEGRAM

Here we see the operator preparing to send a telegram without wires. There is the key, which he is to tap; the battery, which gives the current necessary for sending the message, and the induction coil. At a little distance from the coil we see two brass knobs. One of the knobs is connected to a wire, F, which runs down into the earth. The other knob is connected to a wire, G, which goes out into the air. So long as the key remains untapped, that is to say, so long as the ends of the wires have a little space of air between them, just underneath the knob, the current cannot flow along the wires. The telegraph instrument, without the touch of the operator's hand, is as silent as an unplayed piano. But suddenly an urgent message has to be despatched. The operator presses down the knob of his key. Immediately the current leaps across from the wire A to the wire C, and along this to the coil. It whirls round miles and miles of wire in the coil, gathering intensity at every whirl, then out, along E, to the brass knob.



Making the electric circuit

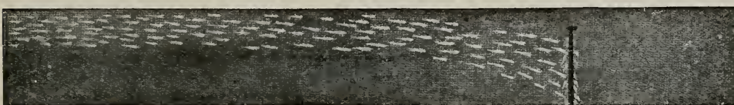
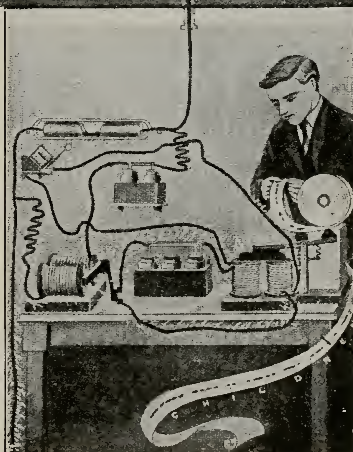
The current from E charges the little brass knob powerfully with electric energy; the other knob is also charged from the coil along D; the electric charge gathers in the knobs until it becomes so powerful that the air between them is unable to keep it apart, and it leaps across the space with a loud crack and brilliant spark; this sends a shock along the wire F down into the earth, and also up the wire G out into space in every direction. The electric current is shown as sparks of light in this picture, but it cannot really be seen. For a dot of the alphabet a single spark jumps from knob to knob. For a dash there is a little stream of sparks. What else happens we cannot see, but we know all the same. When the key is tapped and the spark ends, the message actually begins. Waves are set up in the ether, carrying each dot and dash of our message. Such is the power of electricity working in conjunction with the wonderful ether, an element that not one of us can explain any more than we can explain the electricity itself.

Receiving a "wireless" telegram

Here is the office in which the wireless telegram is to be received. The sender, whom we see on another page, may be thousands of miles away, but the receiving instruments here are in tune with his. The waves which he caused, after traveling for thousands of miles over the ocean, at last reach, in about one-sixtieth of a second, the wire *a*. Through this they pass to the coherer, shown large in this picture for clearness. It is a little glass tube, in which are two silver plugs. Between these there is a little space, which is occupied by loose grains of nickel and silver. The incoming wave causes the filings to cohere, or join together, as we see in the lower picture. The message through *a* now flies across, and through *b* and *c* to the magnet coil. It magnetizes the piece of iron marked *magnet*, which attracts the upright piece *d*, and this enables the message to pass to the wires *e* and *f*, which now form a powerful circuit, working another magnet, which also pulls down another piece of iron, marked *g*.

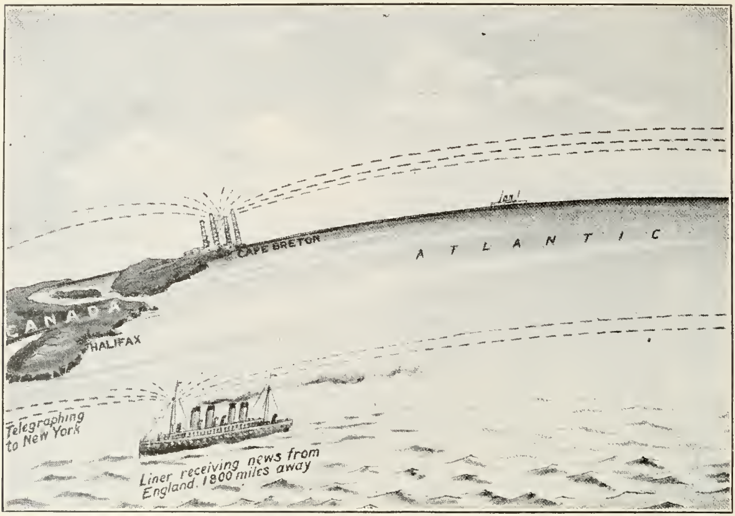
THE ABOVE PICTURE SHOWS THE OPERATOR ABOUT TO RECEIVE A MESSAGE

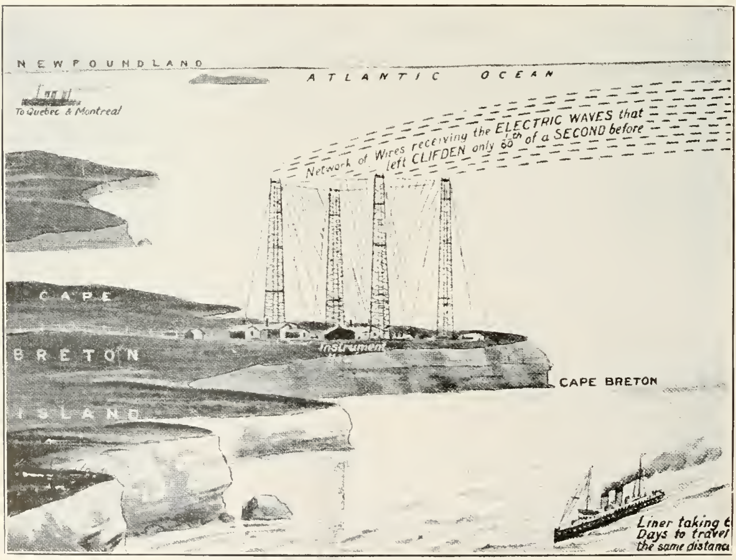
Operator receiving message

Every time the piece of iron marked *g* is attracted by the magnet, it tilts up an inker at the other end, which spells out the message in dots and dashes on a tape, revolving on a wheel by clockwork. This lower picture shows the signs that spell a word being inked on to the coil. The circuit must be broken several times for each word—after each dot or dash—otherwise we could not get our message. This is effected by the little instrument placed just under the coherer, marked "tapper." Directly the filings cohere, the tapper gives it a tap, as shown in the upper picture, and the filings separate, ready to be drawn together by the next electric shock received. The wire *h* is run down into the earth, the great body of which completes the circuit of perhaps 5000 miles. The simplest forms of instruments are shown on these pages, but for long-distance messages more elaborate instruments, with a powerful dynamo instead of a battery, would be used to form a circuit through the ether in the earth.

TRANS-ATLANTIC MESSAGES FLYING THROUGH SPACE

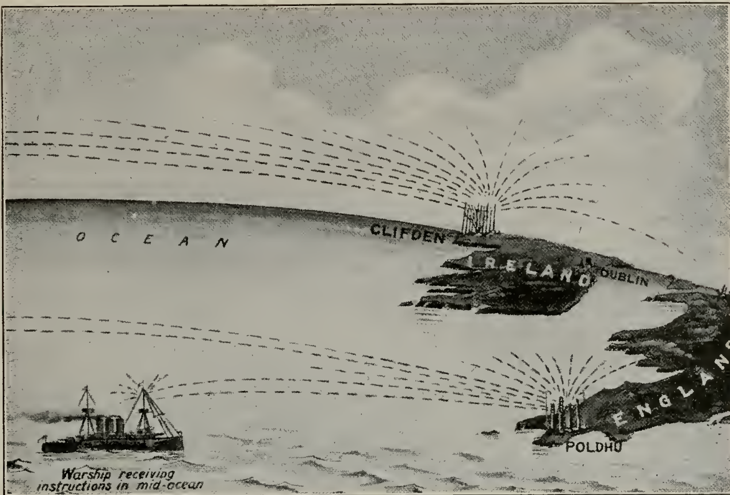


Here we see the latest invention in telegraphy—the wireless system. We tap a key and send a current of electricity along a wire. From the end of this wire the current springs into space and flashes across the sea.

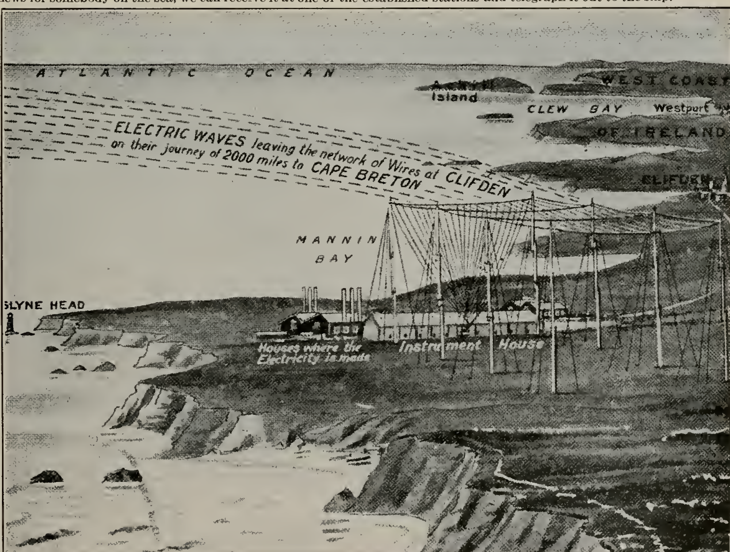


If we want to send a wireless message from Cape Breton, Canada, to Ireland on the other side of the Atlantic Ocean we tap our key, and the message flies through the air, covering the 2000 miles' journey in the sixtieth of a second.

TWO CONTINENTS JOINED BY ELECTRIC WAVES



Not only can we send our messages to an Irish or English station; we can receive messages as well. If we get news for somebody on the sea, we can receive it at one of the established stations and telegraph it out to the ship.



Of course, though we call it wireless telegraphy, we have wires at the receiving and dispatching points. High posts are erected at the instrument houses to catch the waves as they fly to us from those who send the message.

able for them. They put on great coats and wraps, and take to the decks. Before they begin to walk about, however, they think of their families ashore, their wives, husbands, children, sweethearts. They go to one of the rooms on the ship and write messages of affection and good cheer. They ring a bell. A servant comes and the messages are handed to him. They are carried to the clerk in charge of the wireless telegraph. The passengers begin to walk about the liner and to enjoy themselves.

In his little room the operator of the wireless telegraph sits before his machine. On the table in front of him are the messages of passengers, a pile of crowded papers. It is the business of the clerk to send those messages. He flips an A, B, C into the ether, and somehow or another those letters are received on shore. They travel without wings, without wires; they arrive.

A fog descends upon the sea; the engines are slowed; the foghorn begins to sound.

Tap, tap, says the operator, earning his daily bread.

Crash!

A noise like thunder. A shock that sends everything flying. A tearing and rending and splintering of timbers. A dull, thudding crumple of steel plates. The roar of water rushing in. The staggering shudder of the whole ship. Shrieks and cries of people from every quarter. Voices shouting through the fog—loud voices of command. And darkness. Every electric light goes out.

The operator interrupts a sweetheart's message, and taps out the letters C, Q, D, or S, O, S. Through the cries of the passengers, above the shouts of command, piercing the black fog and winging wingless over the ocean, those invisible letters strike on the "receiver" ashore, and on numerous "receivers" aboard other ships, almost at the moment when the operator sets them free. They mean to those who receive them· "Come quick, danger" or "save our ship."

What has happened? The steamer *Florida* has rammed the great White Star liner *Republic*. The water pours in, the crowd of panic-stricken humanity waits for death.

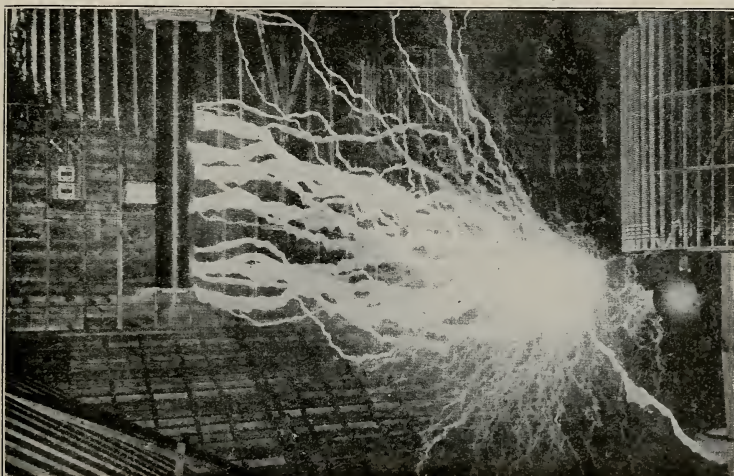
Through it all the operator sits amid the ruin of his office, tapping, tapping, tapping his messages into space.

On another vessel, in another little office, another clerk sits tapping away at the ether. The telegraph operator on the *Baltic* was sending his passengers' messages home when his receiver recorded the distress call from the *Republic*. The sinking ship was sixty miles away, drifting in a dense fog, and the *Baltic* changed its course and set out to find it. From half-past seven in the morning till half-past six at night the *Baltic* scoured the sea, talking all day long to the ship that was sinking with a thousand lives. All day long on the sinking ship sat the telegraph operator, tapping into space a signal of distress. Let us try to imagine the scene. Two ships are in peril in a thick fog. Two thousand men, women, and children prepare to die. In a little room on one of them, a man is tapping at a keyboard, tapping into space a bitter cry for help. The air-waves, set in motion by his tapping, travel sixty miles until they find, on another ship, a sympathetic disk on which they register themselves; and thus the ships' distress is made known.

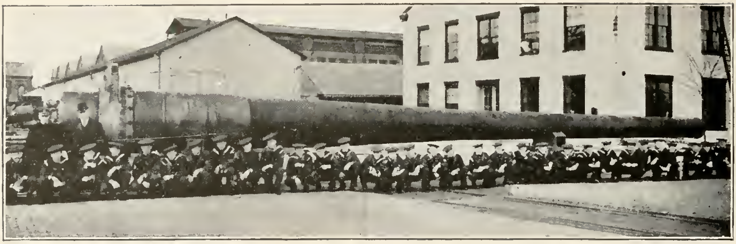
Only a few years ago the *Republic* must have been completely lost, and that catastrophe was saved for the first time in the history of the world, by wireless telegraphy, a power which no man understands.

A STATION THAT TALKS TO ALL THE WORLD

The Tower on Long Island, erected for the dispatch of wireless impulses



An enormous electrical discharge at the Long Island wireless station



MODERN WAR'S MAILED HAND—GUNS AND SHELLS

THE guns carried on ships of war, and used in army fortifications (with the exception of shoulder rifles and revolvers, which are known technically as small arms) range in size from a light automatic machine gun, which weighs about forty pounds, and fires 500 rifle bullets per minute, to a huge monster known as the naval fourteen-inch gun to be mounted on the battleships *New York* and *Texas*, and which weighs sixty-three tons, and fires a projectile of 1400 pounds' weight at the rate of three shots in a minute. Fourteen inch guns of about this size will also be used in fortifying the approaches to the Panama Canal.

THE STEEL USED IN THEIR CONSTRUCTION

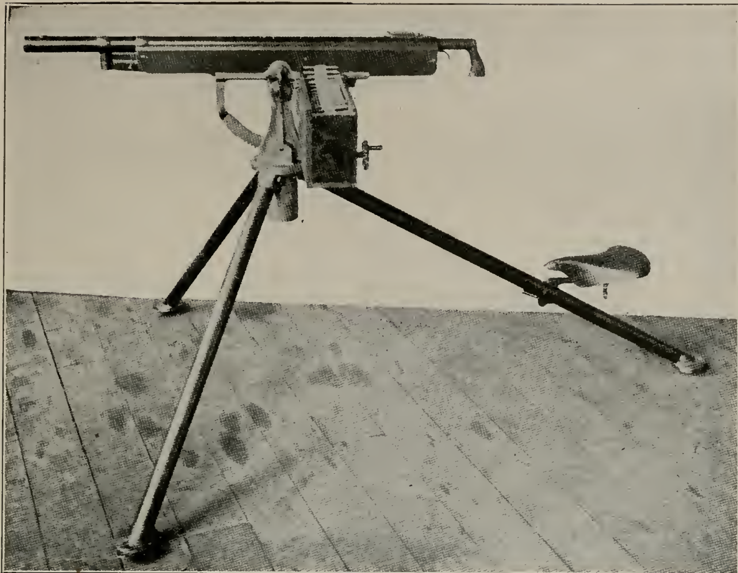
Modern guns are now all built up or assembled from steel forgings which are supplied to the gun shops in the form of rough forged hoops and tubes, slightly larger than their finished size. The steel of which guns are made is of the very finest quality of forgings known, and is supplied to the government by the Bethlehem and Midvale Steel Companies, who have made a specialty of supplying them. These forgings must have the very best treatment, and are subjected to the closest scrutiny both during their manufacture and subsequently during their final machining to size at the gun factory.

It is indeed one of the most interesting facts in connection with the extraordinary development of modern gun construction that the demand for a constantly improving quality of material has led to improvements in the manufacture of steel far exceeding those that might have been expected from the demands of ordinary industries. When it is realized that whenever a large gun is fired the pressure in the bore rises almost instantaneously from 15 pounds per square inch to over 15 tons per square inch, the necessity for the highest grade of material is fully apparent.

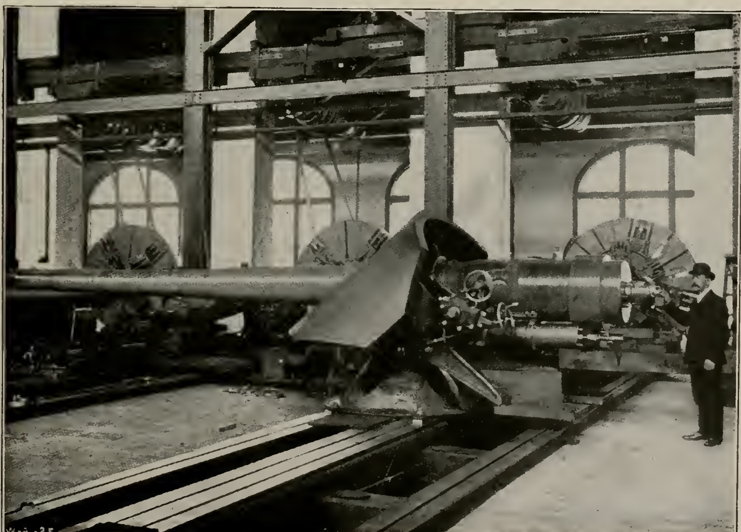
MACHINING THE GUN

The gun hoops and tubes when received at the factory are placed in the large gun lathes and turned down to the required size. In addition to machining the exterior of the hoops or tubes used in building up the finished gun, these parts all have to be bored out so that the inside will be of the required size to fit over the piece next inside it, in the assembled gun. The boring bit, or tool used, for this purpose consists of two cutter tools projecting from a wooden cylinder. In the turning off of the exterior of the forging, it is revolved, and the tools are stationary except for longi-

THE TWO EXTREME TYPES OF BIG GUNS



The automatic action of the gun is effected by means of the pressure of the powder gases in the barrel. The boxes contain one hundred, two hundred and fifty, or five hundred cartridges each, and are so constructed that they can be quickly attached or removed.



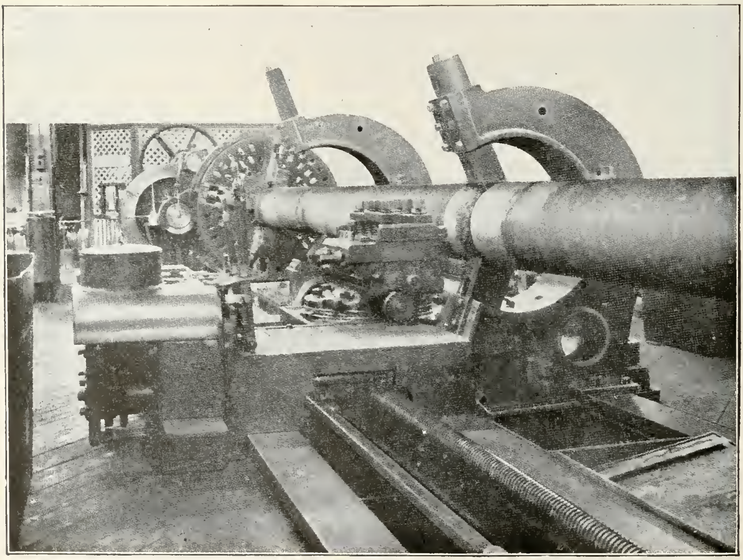
THE MONSTER NAVAL FOURTEEN-INCH GUN

These guns weigh more than sixty tons and fire projectiles of 1400 pounds every 20 seconds tudinal movement so as to cover the whole length of the surface; in the boring operation, on the contrary, the forging is stationary, and the tool revolves and advances slowly through it at the same time. This operation sometimes requires two or three hundred hours to complete. It must be done with extreme accuracy and requires constant checking, for the reason that mistakes cannot be corrected, and the piece would be ruined.

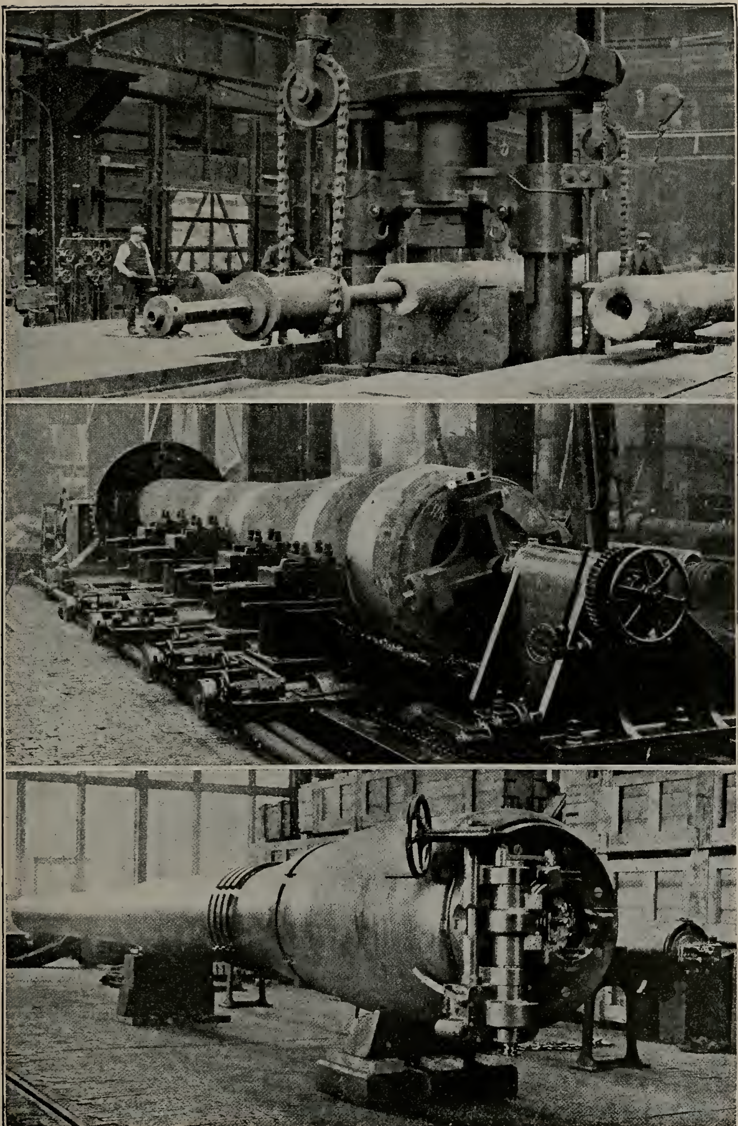
The work of machining gun forgings to finished size calls for the employment of only the most skilful machinists, because the work must be done with the utmost exactness, and the variation from the prescribed dimensions on these long forgings is not allowed to exceed half a thousandth of an inch or the thickness of an ordinary cigarette paper. So carefully are the measurements made that the measuring tools or gauges are held by wooden grips so that the heat of the hand will not warm the metal and make the measurement inaccurate. The temperature of the machine shop is kept uniform throughout, and all measurements are checked on a standard comparator kept in the shop office. During the boring and turning operations above described the forgings are minutely examined for any flaws, cracks, or other defects that might conceal a weakness of the metal. Any defect that cannot be completely removed in machining causes the rejection of the forging.

ASSEMBLING THE PARTS

The next process in the building of the gun is the assembling of the various parts together. Modern guns are assembled by what is technically called "shrinkage;" that is, the finished size of the inside of one hoop is slightly smaller than the outside of the hoop



A FORGING FOR A BIG 14-INCH GUN BEING TURNED DOWN IN A GIANT LATHE TO THE REQUIRED SIZE



THREE STAGES IN A BIG GUN'S GROWTH

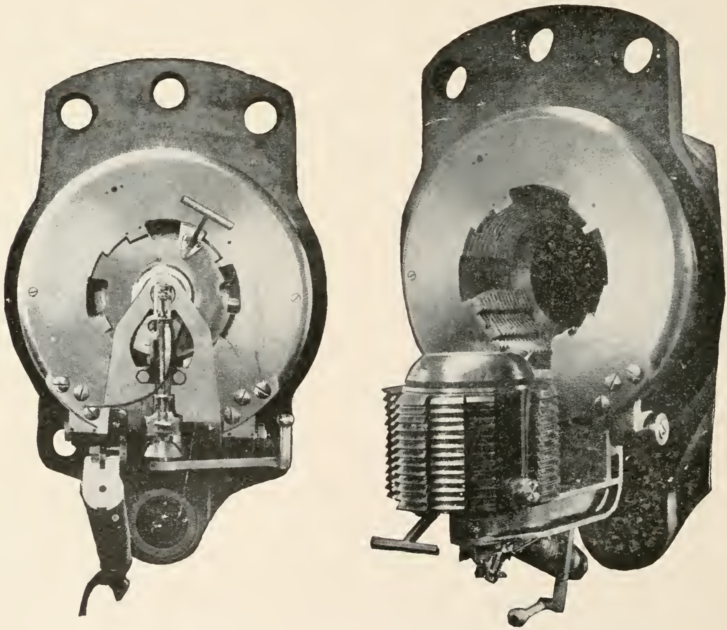
The white-hot ingot in the hydraulic press, which roughly shapes it
The roughly-shaped ingot being turned and worked upon simultaneously by eight cutting tools
The finished gun in the examination shop, awaiting rigid tests before being passed for service

it goes over, and the assembling is done by heating the outer hoop in a furnace until it has expanded sufficiently to go over the cold inner hoop.

Small guns consist of two layers or parts, and the larger guns of four layers of hoops, and 10 or 12 separate parts. Finally, the liner, or inner tube, is inserted in the gun; this inner lining is made so as to be easily removable, and a new one can be inserted when the bore of the gun becomes worn out through repeated firing. The liner is inserted in the gun, the latter having been previously heated in a furnace. This operation requires great skill, as the hole in the heated gun is only a few thousandths of an inch greater in diameter than the size of the liner, and the assemblage must be made rapidly before the gun cools off. When the liner is in place the gun is cooled by spraying it with water and it contracts and holds the liner firmly in place.

Rifling the Gun

The inside of the liner is now rifled, or has spiral grooves cut in it to rotate the shell, and the breech mechanism or arrangement for closing the rear end of the gun after loading, is fitted and the gun is complete. When the breech is first closed the heavy steel plug is swung up and entered in the round slotted hole, with its threads clearing those of the gun; the plug is next revolved so that its threads engage with those of the gun, and lock; thus the escape of



BREECH MECHANISM FOR CLOSING THE REAR END OF A 14-INCH GUN powder gases when firing the gun is confined in the bore of the gun, and the only escape is at the muzzle after the shell gets out. The three round holes above the gun breech shown in the picture are for bolting the gun to its mounting so that it can be elevated or depressed for firing the desired distance.

How classified

Guns are classified according to the diameter of the bore in inches, and according to their length in calibers; a caliber being one bore diameter; thus a 12-inch 50-caliber gun is one that is 12 times 50 inches or 50 feet long; similarly a 6-inch 50-caliber gun is 25 feet long. Guns are built in all sizes. The army 6-inch gun is 310 inches long, is 10 inches wide at the muzzle, and 24 inches wide at the breech. The 14-inch naval gun is 650 inches long, 24 inches wide at the muzzle, and 48 inches wide at the breech. All guns are now built as breech loaders. The English and some U. S. Army guns have wire ribbon wound tightly around the gun, this wire winding replacing some of the inner hoops, but this construction requires a heavier gun in order to get the same longitudinal strength.

THE MAKING OF RIFLES AND AMMUNITION

While most persons of any age have handled guns and ammunition, comparatively few users of guns and ammunition are acquainted with the elaborate processes and the great care and skill that are required to produce them.

Steel used in the manufacture of rifles

The selection of suitable steel is an important requisite in manufacturing guns, as they are subject to tremendous pressures. Nickel steel, which has a tensile strength of over 110,000 pounds and an elastic limit of over 90,000 pounds to the square inch, is used for the barrels of all rifles intended to shoot high-power cartridges; and most of the metal parts of some of the later models of guns are made entirely of this steel, in order to obtain lightness with strength.

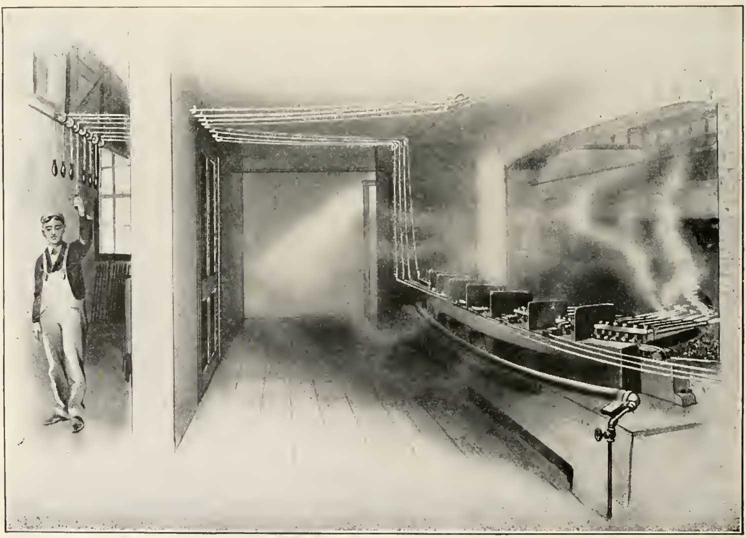
The steel is bought in rods and billets and is manufactured into the barrels and parts in the factory. In making the barrels, the rods are first cut off to the requisite lengths, and, in some instances, forged into the shape required. They are then drilled out and machined and afterwards bored up and reamed to the caliber desired. After this they are "straightened," which is an act requiring delicate and expert treatment. The "rifling" is then put in.

How a modern gun is rifled

This is a series of grooves that run spirally through the barrel, in order to make the bullet spin so it will keep head on. The correct twist of this "rifling" for a given caliber is determined by test and experiment, and the carefulness with which it is worked out has much to do with the accurate shooting of the rifle. Both after boring and "rifling" the barrel is carefully tested and examined, and (in the best factories) given the "lead" test. This test discloses the slightest variation in the diameter of the bore or any imperfection in the "rifling." The barrel is also given a provisional proof, which consists of firing it with a heavy charge of powder, much heavier than it is intended to shoot.

The receiver and most of the other parts of the guns are first forged under drop presses and then machined into the dimensions and shaped required. Each part is carefully inspected and gauged; for the system of interchange-

STRAIGHTENING AND INSPECTING WINCHESTER BARRELS



PROVISIONAL PROOF. FIRING WINCHESTER GUN BARRELS WITH EXCESSIVE CHARGES able parts in vogue in the manufacture of guns makes it necessary that all similar parts should be exactly alike. It is this system of turning out similar parts in large quantities that makes it possible for guns to be bought at such a low figure.

THE PROCESS OF HARDENING THE STEEL

The parts are then hardened, so they will stand wear, by heating them in a furnace and plunging them in oil. This process is regulated, so as to get uniform results. All the furnaces are kept at a uniform temperature by thermometers, which are connected to a central station in charge of a man who gives this matter his undivided attention; and the oil is kept at a fixed temperature by means of a refrigerating plant, also in charge of a man. After hardening, the parts are assembled or put together to make up the guns.

MAKING THE WOODEN PARTS OF THE GUN

The stocks and forearms of standard dimensions are turned out on automatic machines, which work somewhat after the principle of a pantograph. A form or model to give the shape of the stock desired is placed in the machine on one side and on the other side is placed a block of walnut. Between them is a rod, held in position. At one end of the rod is a roll and at the other end a cutting tool.

Both the model and block are revolved and the rod being held against the model at the roller end is forced forward and backward by the revolving model against the revolving block and the tool cuts out the shape of the model on the block. The stocks are then finished by hand, expert wood finishers being required to obtain the smooth and soft effect required in gun stocks.

TESTING FOR ACTION AND ACCURACY

When the guns are put together, they are given a definitive proof, which consists of firing them with a charge much heavier than they are intended to handle. After this they are tested for action and accuracy in shooting. The sights of the rifles are lined up so as to group a series of shots in the center of the target; and the shotguns are shot to show the pattern they make.

Certain high standards are required, and guns that do not reach these standards are not allowed to leave the armory. During the different proofs and inspections, the guns are marked, and these marks show they have passed through the regular series of proofs and inspections.

THE MANUFACTURE OF CARTRIDGES AND SHELLS

In the manufacture of metallic cartridges and shotgun shells, even the metal used is made in the plant. Cartridges are subjected to a very heavy pressure in firing and therefore the metal ought to be exceedingly tough and elastic. By theoretical, scientific and mechanical tests and experiments, the proper ingredients for this metal are determined and a fixed standard adopted. After the different ingredients have been mixed in a retort, the metal is cast into long bars, which are then passed through heavy rolls until they are of the required thinness for making different kinds of cartridges. They then appear like rolls of brass or copper.

These rolls are passed through a press, which stamps out circular disks of the metal and at the same time forms them into shallow cups. These cups are passed through a series of presses, which gradually draw them out into the length required for the cartridges. During each operation the metal becomes very hard and therefore has to be annealed. This is done by heating the cups to a required temperature in a furnace and allowing them to cool slowly. The discoloration caused by this heating is removed by placing the cups in tumbling barrels with sawdust and soda water, from which they emerge bright and shining.

How the head of a cartridge is formed

After the cups have been drawn into tubes, the heads are formed on them. This is done by means of a hollow die the exact shape of the head. This is brought down on the closed end of the tube in a press, and so ductile is the metal that it is forced into the die and assumes the shape of it.

Center fire cartridges have pockets in the heads for the primers. These pockets are punched in before the cartridges are headed. After heading, the tubes are trimmed off the required length for the cartridge, after which they go to the reducing presses to be formed into their proper shape. The bottle-necked cartridges are drawn in at the mouth and others given the taper required. This is done with dies. Practically all the machines work automatically, and are capable of turning out a very large quantity of cartridges every day.

After the shells are formed, the primers are inserted on a machine, which pierces the pocket, so as to provide a hole for the flash, and sets in the primer. The cartridges are then thoroughly inspected for defects, such as dents or scratches, unpierced primer pockets, poor primers, or absence of primers, or primers set in wrong, etc. The cartridge is now ready to receive the powder charge and the bullet.

Automatic loading of cartridges

The loading is all done on automatic machines, which accurately measure the proper charge of powder, seat the bullet firmly and evenly and draw in the mouth of the shell firmly around the bullet. If the proper charge is not delivered to the cartridge, a device on each machine announces this fact instantly.

New cartridges are being constantly designed at the factories, and one of the most important things is to determine the weight and shape of the bullet. This is done by tests and experiments, which often have to be long continued.

The bullets are of many varieties. Some are full lead, others full lead with patches of paper, others steel or cupro-nickel jackets filled with lead; others have steel jackets with lead exposed at the point, in order to produce a mushrooming effect upon impact. This mushrooming effect is very desirable in cartridges for game hunting, as when a bullet spreads out in this way upon striking an animal, it delivers its whole force on the animal and produces a tremendous, shocking effect. To obtain this, therefore, some bullets are very ingeniously contrived.

Round-pointed, flat-pointed and sharp-pointed bullets

The bullets are also of many different shapes: some with round points, some with flat points and some with sharp points. The sharp-pointed bullets have been found to shoot with great accuracy, due no doubt to their greater ease in overcoming air resistance. The jackets are drawn out to the required length from disks of metal, in the same way that the cartridges are, and the lead forced in. Lead bullets are cast in slugs and then swedged to size and shape. The grooves often seen on bullets are put on by machines, which are equipped with two large metal disks with a sharp or a knurled edge, moving in opposite directions, through which the bullets pass while standing with point up.

The cartridges, after being loaded, are carefully inspected before being packed into boxes. For packing some of the smaller cartridges, an ingenious perforated plate is used. This is set shaking, and the cartridges upon being thrown on promiscuously are shaken into the perforations point down. They are then in a condition for quick packing.

HOW SHOTGUN SHELLS ARE MADE

In the manufacture of shotgun shells, the paper tube is important. This tube is made on a machine from a sheet of specially manufactured paper, cut to a fixed size. The sheet is fed through the machine, coated with paste, spun into a tube around a mandrel and ejected. This is all done automatically and the sheets follow one another in rapid succession. The color is given to the shell by coloring the sheet of paper two or three inches from the end. The tubes are then burnished, placed into a water-proofing solution for a stated time and dried in ovens, after which they are gauged or sized to the required dimensions. They are then cut into shell lengths. This is also done by an automatic machine. The tubes feed down from a hopper at the top of the machine and are grasped and drawn in front of the revolving cutters by a shifting slide, when the cutters move forward and simultaneously cut the tube into the lengths required.

The brass heads of the shells are drawn out of cups of brass in the same manner as the cartridges, and the pocket made for the primer. The brass heads and the paper tubes are now brought over to the assembling machines. The brass heads are placed in a hopper at the top of the machine to be fed down and the tubes are placed on spindles on a dial, which move around and under a punch at the same time that the brass head is fed down on top of the tube. In the meantime a ribbon of narrow cut specially prepared paper, which unwinds on a spindle at the left of the machine, is spun into wads and inserted into the tube to be pressed into the head of the shell to form the base wad. The shell is then carried over to another machine alongside, which shapes the head. From there it is carried to still another machine, which pierces the primer pocket and inserts the primer.

The shell is now ready to be loaded, but it is first carefully inspected for various imperfections which are liable to occur during the process of manufacture. The loading is done on automatic machines, which accurately measure the specified quantity of powder and shot and place them in the shell, together with the wads selected, and then crimp and eject it. During the process of loading cartridges and shotgun shells, samples are taken from time to time and tested for pressure, velocity, accuracy, pattern, etc. The smaller cartridges are tested by shooting them from a mechanical rest; the larger ones are shot from the shoulder with a muzzle rest.

IMPORTANCE OF GOOD PRIMERS

Of much more importance than many people suppose is the primer. As most primers nowadays are required to ignite smokeless as well as black powder, they must emit a particularly strong and hot flash. They must also flash instantly the firing pin strikes them; otherwise there is a hangfire, which is apt to cause danger. In preparing, the object is to get a mixture that will be safe to handle when packed in cartridges, and yet be sensitive enough to respond to the blows of hammers of all properly made guns and be quick and thorough in ignition. It is also important to get a combination that will

TESTING RIFLES FOR ACCURATE SHOOTING AND LINING UP THE SIGHTS

WINCHESTER SHOT TOWER, 182 FEET HIGH. THE TALLEST REINFORCED CONCRETE BUILDING IN THE UNITED STATES not send off gases that corrode gun barrels. These desirable results have all been obtained.

The cups are stamped out of brass of a determined thickness, as well as the anvils which go inside. The mixture is then placed in the cups in a moist state and the anvils inserted. The mixture lies between the wall of the cup and the anvil. When the firing pin is driven against the primer, its wall is forced in against the anvil and the friction causes the mixture to explode and the flame thus made shoots out each side of the anvil where it is cut away, and into the powder charge.

Pressures are determined by noting the compression of metallic disks at the time of firing a cartridge. The ballistic laboratory is equipped with a pressure gauge for each different kind of cartridge. Both the pressure and the velocity are often determined at the same time.

Torrents of Molten Lead

The shot that goes into shotgun shells is made in a building known as a shot tower. The building is in reality a huge machine, and the entire process of manufacturing shot, after the pigs of lead are put into the melting pot, is taken care of by automatic machinery. The lead runs from the melting pot into a pan, the bottom of which is composed of a screen; the size of the screen varying according to the size of shot desired. Through this screen the lead falls in drops like rain, and is caught in a tank of water below. In its fall it assumes a spherical shape.

It is raised from the tank by an endless chain into a long perforated cylinder, which drains off the water. From this it descends into a long, tight, revolving cylinder, which is heated by steam, and there it dries. A small quantity of graphite is put into this cylinder, which gives a fine polish to the shot.

How the Shot Is Sorted and Sized

From the cylinder the shot is raised almost to the top of the building, where it begins to flow down the sorting tables. These are shelves of plate glass, having a slight downward pitch and broadening towards the front. In front of these is a trough, placed at such a distance that only the spherical shot, racing down the inclined shelf, will reach it. The imperfect or flat-sided shot, sliding or traveling more slowly, drop over the edge of the shelf into the scrap kettles below and is later melted over. There are a number of these shelves, set one below the other and facing in alternate directions. By the time it has passed over all these shelves it is safe to say that only the good, well-rounded shot continues on its journey.

It then runs into the sizing screens. These are truncated-cone-like cylinders, having perforations of different sizes, and are set one below another. The size of the perforations corresponds to the size of shot of a certain number, such as No. 4, No. 5, No. 6, etc. The larger size is unable to pass through the first screen and is therefore led off. The smaller sizes pass through to the screen below, and the next larger size is there led off; and so on, down through the different screens, until all the sizes are assorted and led off to their respective places. These sizing screens are continually revolving.

After being assorted for sizes, the shot descends still further into long revolving cylinders, where it is given a final polish. Upon entering these cylinders, it is weighed by automatic scales. The shot is now finished and descends to tanks below, which are numbered with the respective sizes.

THE NEWEST INSTRUMENTS OF WAR

THE SUBMARINE BOAT—SUBMARINE MINE—TORPEDOES—SHRAPNEL—AIR SHIPS—AEROPLANE—ZEPPELIN'S—AIR BOMBS—INTRENCHMENTS—SIEGE GUNS—COAST DEFENSE.

Many of the instruments of modern warfare are almost as startling as was the use of gunpowder, in the Fourteenth Century, at the battle of Cressy. Today electricity and gasoline are of equal importance with powder and shot.

In addition to highly improved rifles and machine guns, field pieces and howitzers there is a long line of instruments calling for the last degree of efficient mechanism.

There are dynamos that supply the currents for the strong searchlights, whose long pencils of light sweep the sky for aircraft or the terrain opposite for the enemies infantry; telegraph and telephone nets are spread out from the tent of a commanding general to the firing line itself; there are mixing machines to supply concrete for the bases of the heavy guns that batter down fortresses; gasworks travel on rails and highways to supply hydrogen for balloons; traction engines haul heavy cannon and caissons; armed and armored automobiles and aeroplanes whir over roads and through the air; armored trains crash into columns of troops and deliver broadsides; in short, every branch of mechanical and chemical science is utilized to the utmost to extend the range and intensify the deadliness of death dealing instruments.

Probably the two most effective of the new engines of war are the submarine boat and the airship—both aeroplane and Zeppelin.

THE SUBMARINE BOAT AND ITS WORK OF DESTRUCTION

The following description of the construction and operation of the submarine will apply in its principles to most of the various types employed.

The form of the hull is generally described as cigarshaped. It is built of the very best quality of mild steel, and the workmanship is of the highest order, for the reason that every seam and rivet must be perfectly tight, in view of the service which the boat is called upon to perform. Not only do vessels of this type undergo all the stresses of sea and weather to which other vessels are subjected, but in addition they are required to navigate at considerable depths below the surface of the water. At these depths the pressure of the water is great, so that the hull must be made sufficiently strong to withstand it.

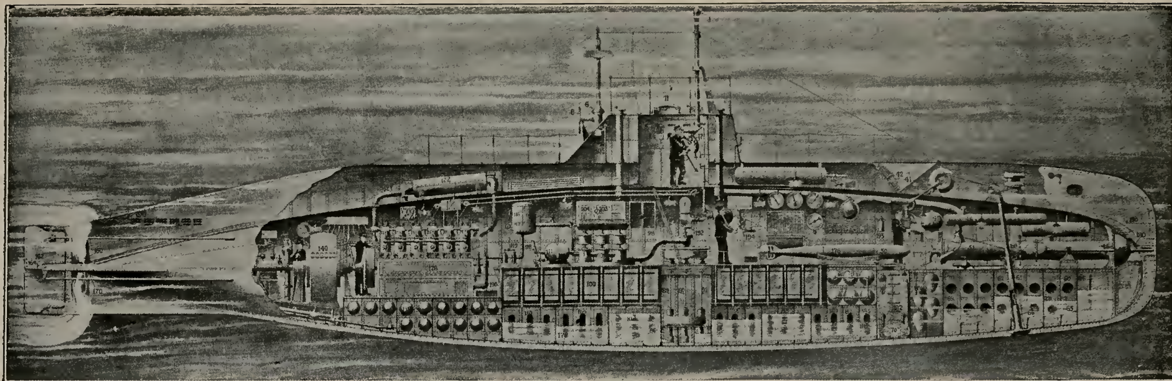
For submerged work large storage batteries are provided, which furnish energy sufficient to drive the boat from ten to eleven knots for a period of over an hour. The same electrical energy will drive it at a lower speed for a much longer time.

There are two distinct conditions in which the boat may be used. In the first, commonly known as the surface condition, the boat is prepared for cruising. A considerable portion of its hull is above water, a removable navigating bridge is in place, and it is driven by large, powerful, internal-combustion engines. Under these conditions it is managed in about the same way as any vessel built to run upon the surface.

The second distinct condition exists when the boat is submerged. To pass from the surface to the submerged condition, certain valves in the interior of the boat are opened. This allows the water from the sea to run into great tanks built within the boat, and thus virtually sink it. These tanks are closely gaged, so that just the required amount of water is taken in. Under normal conditions, when the boat is at rest with the ballast tanks filled, it will have a few hundred pounds reserve buoyancy, which is represented by the top of the conning tower protruding above the water. If desired, this buoyancy may be entirely destroyed by admitting a small additional amount of water, equal in volume to the volume of that part of the conning tower above water. While in the submerged condition, all communication with the outside atmosphere is necessarily cut off. The crew then breathes the air contained in the body of the boat. The amount of air originally contained within the hull is sufficient to support life with comfort for at least twenty-four hours. But, in addition to the air thus contained, the boat carries a large supply of compressed air in steel flasks, which, if used for breathing purposes, would be sufficient for a number of days.

After having brought the boat to the submerged condition in the manner above described, powerful electric motors are started by throwing in a switch. These motors derive their energy from storage batteries contained in the boat, and drive the propellers. The same storage batteries furnish current for numerous auxiliary motors used for pumping, steering, handling torpedoes, etc.

The motion of the boat when under way is controlled by two sets of rudders; one of these sets, known as the vertical rudders, directs the boat's course to port or starboard just as does the rudder of an ordinary ship. In addition, there are provided horizontal rudders, which serve to control the motion of the boat in a horizontal plane; that is to say, the depth at which she runs is regulated by these rudders. For steering in the horizontal plane, instruments are provided, so that the boat may be navigated with the same degree of accuracy as boats on the surface. The first of these instruments is known as a periscope. This consists of a vertical tube which extends from above the surface of the water to a few feet within the submarine. At the top of the tube is an object glass; at the bottom an eye-piece. Two reflecting mirrors one at the top, the other at the bottom of the



THE HIDDEN DEATH OF NAVAL WARFARE; A REMARKABLE INTERESTING SECTION OF A SUBMARINE

1 Periscope.
6 Surface helm compass.
8 Surface steering wheel.
11 Central access hatch.
17 Under water compass.
41 Torpedo intake runway.
42 Water-tight torpedo hatch.
46 Torpedo tube air tank.
49 Torpedo cap.
50 Torpedo.
51 Torpedo launching tube.
52 Cable nipper.
60 Fuel tank.
62 Fuel tank.
65 Collision bulkhead.
66 Mushroom anchor.
69 Submarine mine compartment.
70 Submarine mines.
76 Submarine mine discharge hatch.
77 Forward air flask compartment.
78 Compressed Air Flask.
81 Forward battery set.
82 Balancing tank (forward set)
90 Fuel oil tank.
98 Emergency ration locker.
100 After battery set.
108 Balancing tank (after set)
115 Vacuum tank.
122 Muffler.
128 Main engine.
140 Main motor.
151 Intake pipe from sea opening.
160 Propeller.
162 Steering rudder.
164 Diving rudder.
170 Fair water propeller.
176 Torpedo cradle.
177 Torpedo breech block.
180 Outer torpedo discharge tube.
190 Normal water line (above water).
191 Fire hose.
194 Diving rudder angle indicator.

CHARGING A TORPEDO-TUBE IN A GERMAN SUBMARINE

Most German submarines carry three torpedo-tubes; some later vessels have four. The tubes (as in the boats of all navies) are built into the structure of the vessel, which has, therefore, to be headed exactly in the direction the torpedo is to take—"laid" on the enemy, just as a gun is pointed. A torpedo-tube is simply a metal tube into which the torpedo fits closely, with hinged door-flaps at each end. The torpedo is slid in, the inner door closed and the outer opened. A valve in the tube is opened by electricity and the torpedo shot out by means of compressed air A guiding bar holds it until clear of the vessel and starts the propelling mechanism of the torpedo, releasing also the safety-catch of the detonator of the explosive charge.

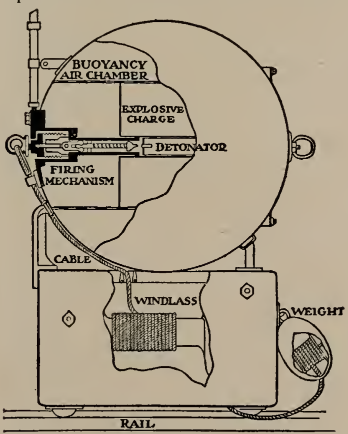
vertical tube, cause the image to be transferred from the object glass to the eye-piece. The operator can turn the periscope so as to sweep the whole horizon. The view thus obtained is as clear as though he were at the surface looking through an ordinary field glass. Hence when running submerged with the top of the periscope just out of the water, the navigator can see with perfect ease surrounding objects. If for any reason it should be desired to run at a still greater depth, compasses are provided by which the course may be steered with accuracy. For steering, submerged, in the vertical plane, instruments are provided which in a way take the place of the compass. One of these is a large pressure gage, which indicates the depth at which the boat is running. Another is a form of spirit level, which indicates the inclination of its axis. By the use of this, the man controlling the horizontal rudder is able to run at a perfectly even depth. While in the submerged condition, the boat is of course amply illuminated by electric lights.

The arm of the submarine is the automobile torpedo. A number of these may be carried. They are discharged through torpedo tubes located in the bow of the boat. Any modern type of automobile torpedo may be used. In view of the fact that the submarine is enabled to approach unseen to within a few yards, if desired, of the most powerful battleship, a long-range torpedo is not required. For this reason the weight devoted to motive power in the ordinary torpedo may be largely used to increase the destructive power, so that the proper arm for the submarine would be far more powerful and destructive than the ordinary automobile torpedo.

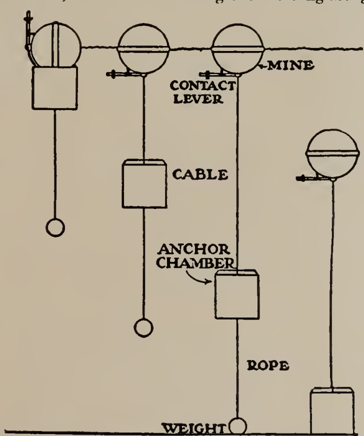
THE SUBMARINE MINE

To-day the mine is still looked upon as a great defensive force, and used pretty extensively in defending war ports. Wet gun-cotton is the explosive now almost universally employed; it has the advantage of being slow to explode, and can be moved and manipulated without very much danger to the submarine miners. By a new process the gun-cotton is now compressed into solid blocks of any desired size or shape, and these are placed in the iron cases. The cylindrical form of case is usually employed. This is made of wrought iron riveted together, and is nothing more nor less than a large ball on which chains are attached so that the mine can be moored in the desired position. The spherical case has been adopted as the result of exhaustive experiments, by which it was found that this form is most capable of withstanding external pressure, and offers the least resistance to tidal currents; it is, therefore, the least liable to be affected by an enemy's attempts at countermining.

The type of mine now generally employed is made to contain a 100-pound charge, if used as a buoyant mine; if used as a ground mine, a cement lining is formed inside the iron shell, and 500 pounds of explosive packed within. The type is excellent for harbor defence, and is used as a ground mine, it can be placed under the fairway of the ships, and is connected by electric cable with a station ashore. By this means a channel right through the center of the mine field is found, so that friendly vessels, knowing the course, can come or go without danger, but should a hostile ship attempt to rush in, then these sinister globes nestling along

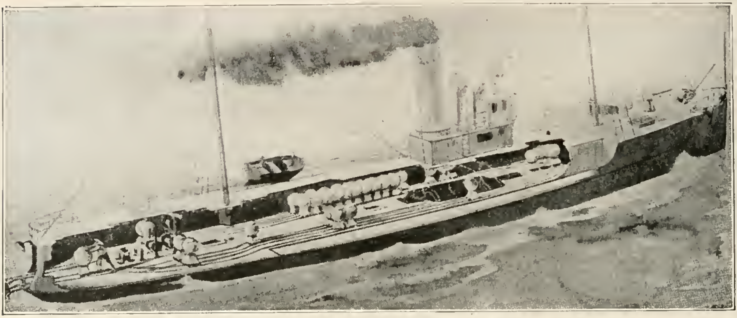


It consists of the mine itself rigged with a lever for setting off the explosives, an anchor chamber connected with the mine by a cable which is as many feet in length as the mine is to be under water, and a weight connected with the anchor chamber.



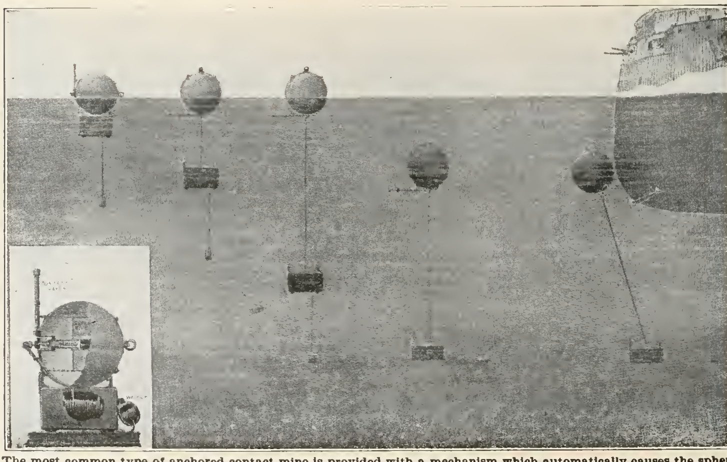
When the mine is dropped overboard as shown (on the left) the anchor chamber plays out cable and sinks until the weight reaches the bottom (as in the third diagram) which stops the cable from unwinding further and pulls the mine below the surface (as in the right hand diagram)

A SUBMARINE ATTACKING A BATTLESHIP AT CLOSE RANGE



SECTIONAL VIEW OF A MINE-LAYER

Showing how the mines are stored and launched through a special port-hole in the stern.



The most common type of anchored contact mine is provided with a mechanism which automatically causes the sphere containing the explosive to float at a predetermined depth of about fifteen feet.

THE BOMB-DROPPER'S WEAPON—USED BY AEROPLANES AND ZEPPELINS

The photographs show (1) The Zeppelin shed at Bickendorf; (2) The Zeppelin shed at Düsseldorf; (3) An air-bomb; (4) The method of dropping bombs from aeroplanes; and (5) Flight Lieutenant Collet of Allied Armies.

the sea bottom, can be instantly fired from the land.

Mines are usually moored about twelve feet below the surface, and kept in position by a heavy iron sinker resting on the bed of the harbor. The latter is connected to the floating mine by a stout chain cable. The mine can either be fired from the shore, or—when a detonator of fulminate of mercury, in connection with a small priming charge of dry gun-cotton is used to explode the mine—by contact with a ship.

But now we must look upon the other side of the picture—i.e. what is done to combat the terror of the mine? Here we come upon perhaps the strangest vessels to be found in any fleet. They are nothing more than the trawlers painted the familiar navy grey, and specially adapted, not for the trawling of cod but for a more difficult and dangerous role—the creeping or trawling for submarine mines!

The method employed is simple and ingenious. Assuming that a certain mine field has to be "cleared," two or more of these "creepers" steal outside the mine area, each towing well astern, sunk to the sea bottom, a heavy iron sinker, or, to employ its correct name, a "kite." This large casting is V-shaped, and attached to it is an iron pulley or block; through this runs the "sweeping-wire," which is attached to a hauling drum on the deck of the trawler, and passes over the stern, and then, going through the block of the kite, stretches away across the sea bottom to the second kite, trailing behind the sister "creeper" on the opposite side of the mine field. The necessary cable being swung out, the two vessels creep ahead in direct line. Well astern, at the bottom of the sea, trails the sweeping-wire, which, passing slowly along, naturally catches the sinkers and chain of the mines. Thus these dangerous fish are swept together; even if one or more do explode, there is no danger to the ship employed, as it is well out of the way. When all the mines are drawn together, a large charge is placed in position, and the whole lot destroyed.

SKY TORPEDOES

Two types of bombs are used from the Zeppelins. One is an ordinary globular grenade, to which is attached a tail of linen to guide it in its flight, and the other takes the form of an "aerial torpedo." This is fired from the gondolas of the airship from a special launching tube placed upon a mounting with a universal joint so that the tube can be swung to any angle and the torpedo sent upon its journey by simply pressing a trigger.

The deadly weapon itself consists of a pointed shell, approximately 20 inches long by 4 inches in diameter. In the nose is a high explosive which is fired by a percussion cap on contact. Beyond this is another compartment that contains the propellant, which is a slow-burning compound composed of sulphur, saltpetre, charcoal and vegetable oil, weighing four and one-half pounds. This when ignited gives off gasses produced by its combustion, which in turn drive a powerful turbine in the rear of the torpedo, and by this means it is driven forward at a high velocity and at the same time imparts a rapid rotating motion as if it were fired from rifled cannon, which, of course, adds considerably to its efficiency.

The aerial torpedo has a stout shell of steel and gives off no flame, which, of course, would be dangerous to a gas-filled Zeppelin. The impetus imparted to the torpedo by the turbine is remarkable, and allowing for the speed of the airship the shell can be hurled with great accuracy.

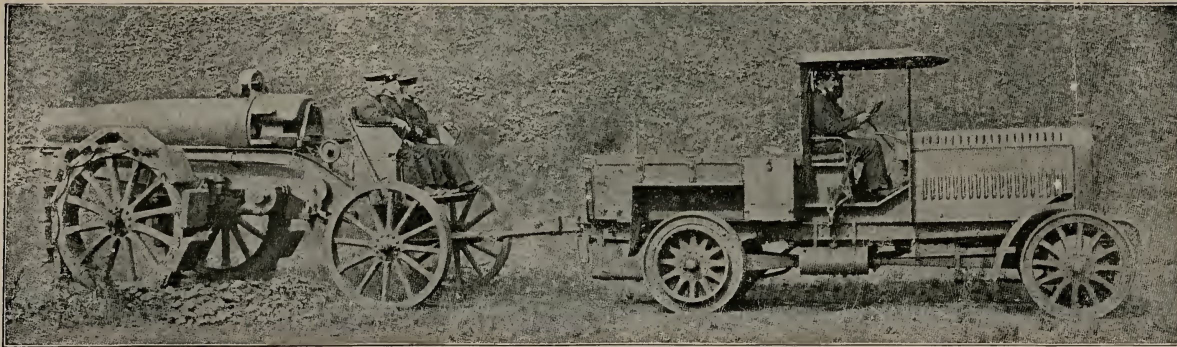
It is interesting to note that the path of a falling body when merely dropped from the Zeppelin is composed of two motions, the forward motion of the object at the moment of release from the moving Zeppelin and the downward path due to gravity. In the case of light objects, experiments prove that when released from aeroplanes they rapidly pass astern.

MAKING THE BIG GUNS

A fascinating sight is to watch the first stages in the manufacture of the big guns. A solid ingot of steel, some fifty feet in length and weighing about 100 tons, is employed in the making of a thirteen-inch gun. After being forged and then allowed to cool, so that it may be toughened for the heavy work, this gigantic bar of steel is pressed into cylindrical shape by a powerful hydraulic press, which exerts a pressure of anything between 5,000 to 10,000 tons to the square inch. Later what is known as the trepanning operation is carried out, namely, drilling the bore from end to end. Next the bore is rifled.

The most impressive sight, however, is the hardening process, when the rough weapon is heated to dazzling white heat and plunged into a well full of oil. If the operation takes place in the night time the sight of this big, glowing bar of metal being lowered apparently into the bowels of the earth issuing leaping tongues of flames from the burning oil, may be likened to a scene from Dante's Inferno. The gun is left to cool in the oil bath, out of which it comes hardened, toughened and tempered.

Now follows the wire-winding operation to make the weapon stronger and impart to it some measure of elasticity. This wire-winding is much the same in principle as the whipping on the handle of a cricket bat. In this case, however, the whipping takes the form of a strong steel ribbon, which is wound around the body of the gun. Every thirteen-inch gun has about 120 miles of this steel ribbon wound about it. Some idea of the labor involved in the manufacture of one of these guns may be gathered from the fact that from start to finish the time occupied is twelve months.



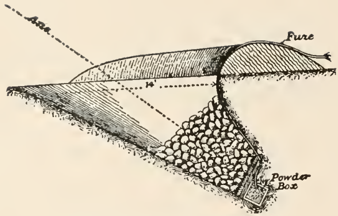
THIS IS THE KRUPP 11-INCH SIEGE GUN WHICH REDUCED THE FORTS OF LIEGE AND NAMUR

The German 11-inch mortar marks a great stride in power and weight and particularly in mobility, over any other mobile artillery as yet constructed. The outstanding feature of this great mortar is that it is so mounted that the gun and its carriage can be hauled either by motors or by horse-power at a speed approximating that of the lighter siege artillery, and that when it has reached the designated position, it takes but a short time to have the gun in battery, ready for the attack.

The barrel of the gun is made of steel, and it consists of the inner tube and an outer jacket, the total length of the gun being 11 feet. The breech is opened and closed by turning a handle through a horizontal arc for about 135 degrees; and a safety device operated by hand is provided which prevents premature firing or accidental opening of the breech. In spite of the fact that the breech mechanism weighs over 1,100 pounds, the construction is such that the opening and closing of it can be effected easily with one hand and in a few seconds' time.

The gun is transported on two separate vehicles, each of which can be hauled as shown in our illustration by a single motor truck. During transportation one unit consists of the gun carriage, slide, recoil cylinders, trail, and permanent axle and wheels, the last-named being fitted with broad flat feet after the manner of the Diplock pedrail. The after end of the trail during transportation is mounted upon a pair of wheels as shown in the illustration. The gun itself is transported upon a carriage upon which it is placed in such a position that the majority of the weight will come upon a pair of pedrail wheels.

To mount the gun when it has reached its assigned place, all that is necessary is to back up the section carrying the gun against the section constituting the mount, and then, by means of wire cables, draw the gun forward into the sleeve and bolt the lug (which is shown on the top of the gun near the breech) to the piston rod of the recoil cylinder. The gun transporting section is then drawn away, the trail is lowered to the ground, and the gun is ready for firing.

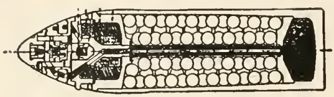


A TYPE OF THE LAND MINE

SHRAPNEL

When the artillerists figured out the problem of scattering projectiles so that even thinly distributed soldiers would be reached, the result of their figuring was the shrapnel shell.

This is a hollow steel projectile, packed with bullets, and containing a charge of powder in the base. It is exploded by a time fuse, containing a ring of slowly burning composition which can be set so as to fire the powder during the flight of the shell when it has traveled to within fifty yards of the enemy. The head is blown off and the bullets are projected forward in a sheaf, spreading outward as they go. An 18-pound shell covers a space of ground some 300 yards long by 35 yards wide with its 365 heavy bullets.

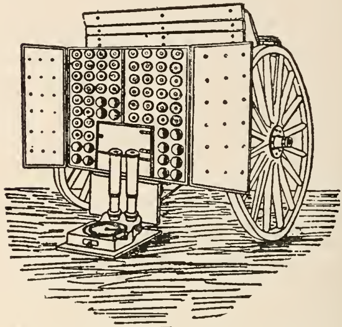


HIGH EXPLOSIVE SHRAPNEL

If the time fuse is set the projectile bursts in air, the base charge driving out the bullets which scatter and give the shrapnel effect; otherwise the projectile bursts on impact.

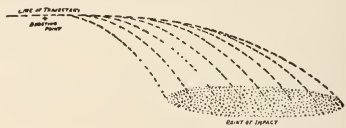
When shrapnel came into use most nations abandoned the common shell. But shrapnel proved almost ineffective against the shielded gun and the gunners were indifferent to the bullets pattering on the steel shield in front of them. The answer to this was the high-explosive shell, a steel case filled with high explosive, such as melinite, which is the same as lyddite, shimose, or picric acid. This, when detonated upon striking a gun, can be relied upon to disable it and to kill the gunners behind it.

A shell is now used which combines the action of the shrapnel and the high explosive shell has been introduced. This is the "universal" shell invented by Major van Essen of the Dutch artillery. It is a shrapnel with a detachable head filled with high explosive. When burst during flight it acts like an ordinary shrapnel and the bullets fly forward and sweep the ground in front of it; at the same time the head, with its explosive burster, flies forward and acts as a small but efficient high explosive shell. These projectiles have been introduced for howitzers and for anti-air-craft guns, and some of the nations with new equipments have them for their field guns.



A CAISSON OR AMMUNITION WAGON

Which is set by the side of the gun in action. The device on the ground is a mechanical fuse setter by which the point of the explosion of the shell in the air can be regulated.



The ground covered by a shrapnel is elliptical in form and at the effective ranges does not exceed 200 yards in depth by 25 in width. Shrapnel is the most important projectile. The case is of drawn steel with solid base The mouth of the case has an aluminum head screwed in and tapped to take a combination time and percussion fuse. The case contains 262 balls, each 0.49 inch in diameter. The bursting charge consists of $2\frac{3}{4}$ ounces of loose black powder; it is placed in the base, and covered by a steel diaphragm. The fuse is timed so that the case will burst just in front and above the trenches or line of troops.

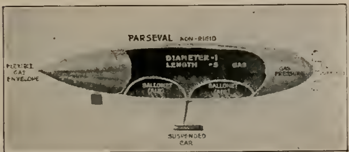
VALUE OF FAST AEROPLANES

Aeroplanes are faster and more powerful now than they ever were, not so much because they must cover much ground quickly as becase they must be able to attain greater speed so as to choose their own position and pour in a destructive hail of bullets.

The great, rigid Zeppelins alone can hope to contend with high-powered aeroplanes; for they have been so far improved that their average speed was increased to over sixty-three miles an hour, and their maximum speed, with the wind, to ninety-four miles an hour. Armed as they are with machine guns and capable as they are of rising to safe heights twice as rapidly

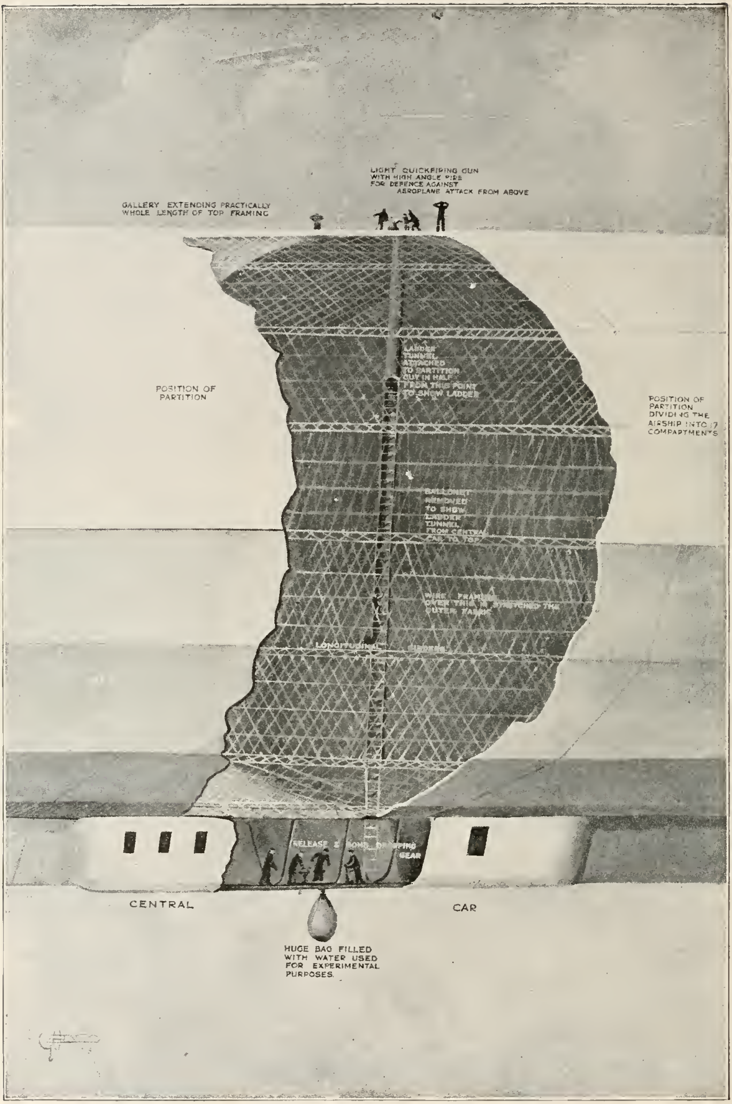
This photograph shows a huge German airship blown out of its course and compelled to descend. The little aeroplane hovering overhead seems a midget by comparison. It is a matter of controversy whether the airship or the aeroplane is likely ultimately to prove of greater value in the service of man.

Of the three types of the dirigible the Zeppelin, with its rigid framework of aluminum protecting its separate ballonets and its great length, has little head resistance in comparison with its size, and slips through the air with little friction.



The semi-rigid, represented by the Parseval type, has a stiffening keel to keep the balloon in shape.

The non-rigid feels the effect of air pressure (tending to force the bag out of shape,) most of all.



AMIDSHIPS SECTION OF A ZEPPELIN

The fabric has been cut away to show the delicate array of steel and aluminum. A ladder passes right through the center of the vessel from the central car to the top of the envelope. This top is strengthened by steel framing, and upon it is mounted a light quick-firing gun to defend the ship against aeroplane attack from above. The gun platform is placed over one of the seventeen partitions of the Zeppelin's envelope.

as the highest powered aeroplane, they must be regarded as veritable battleships of the air.

But why are there both aeroplanes and airships? For the same reason that there are dreadnoughts and torpedo-boats. Each has its own function. Aeroplanes are useful chiefly for tactical reconnaissance; in other words, for scouting after armies have entrenched themselves and unlimbered their artillery. Airships are useful chiefly for strategical reconnaissance; in other words, for scouting at a time when armies are moving towards the terrain which they intend to occupy. Although aeroplanes, guided by skilful pilots of marvelous endurance, have stayed aloft continuously for more than twenty hours, the strain is too great for ordinary human nerves. Even a continuous flight of five hours makes inordinate demands on a pilot's nervous force.

AEROPLANES EQUIPPED WITH MACHINE GUNS

Most military aeroplanes carry two passengers seated in tandem. One man guides and controls the machine, the other observes the terrain below and manipulates either a rifle or a machine gun. Single-seated machines are also used, but machine guns cannot be successfully fired by an aviator whose hands and feet may not leave the controls. To engage in a machine-gun or rifle duel 5000 feet above the ground requires courage of a kind that surpasses the heroism recorded in the epics of old. Indeed, there is nothing in all Homer which for sheer daring can be compared with the feat that a fighting air scout is called upon to perform.

If an aeroplane flies at a height greater than 4500 feet it is reasonably safe from the fire of rifles and artillery on the ground. But at that height it is extremely difficult to reconnoiter successfully. Whole batteries seem more like minute crawling insects than guns and men, and it is difficult to distinguish cavalry from horse artillery. The temptation to descend into the danger zone in order to see more clearly is strong.

ADVANTAGES OF THE DIRIGIBLE

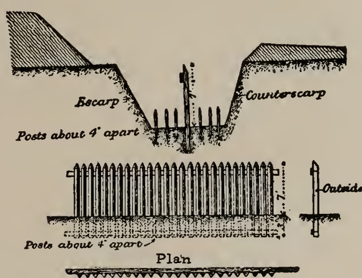
The commander of an airship is as much at his ease as the captain of an ocean liner on his bridge. He can move about in more or less comfort; he can hover over one spot for hours and study the operations below at his leisure, if he is not disturbed by a flock of two-seated aeroplanes carrying rifles; he can stay aloft for a whole day without fatigue. More important still, he has at his disposal wireless apparatus which enables him both to send and receive messages for 300 miles without the necessity, therefore, of immediately reporting each important discovery in person.

In lifting capacity, too, the airship is vastly superior to the aeroplane,—a factor of importance because if explosives are to be dropped, the dirigible airship can carry not only more bombs but much heavier bombs than an aeroplane. What is more, the airship's ability to float stationary over a given spot (an aeroplane must be in constant motion to stay aloft at all) enables it to drop a hundred-weight of explosive with a reasonably true aim.

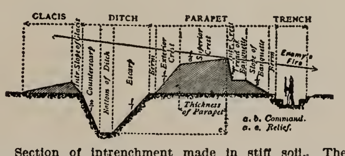
All these frightful advantages have been developed to the utmost in Germany's colossal Zeppelins,—slim cylinders as big as ocean steamers that slip through the air with a certain sureness. They have searchlights for nocturnal scouting, armor to protect their motors, wireless outfits almost as powerful as those of a transatlantic liner, machine guns on top of their long gas envelopes to beat off attaching craft, a crew of twenty, provisions and fuel for a journey of 3000 miles, and bombs formidable in size and number. Compared with them other German dirigibles, as well as the non-rigids of France, Germany, and Russia, seem what they are,—great mechanically propelled bubbles of hydrogen gas and not real ships of the air.

THE SILENT DEATH, THE NEW WAR WEAPON

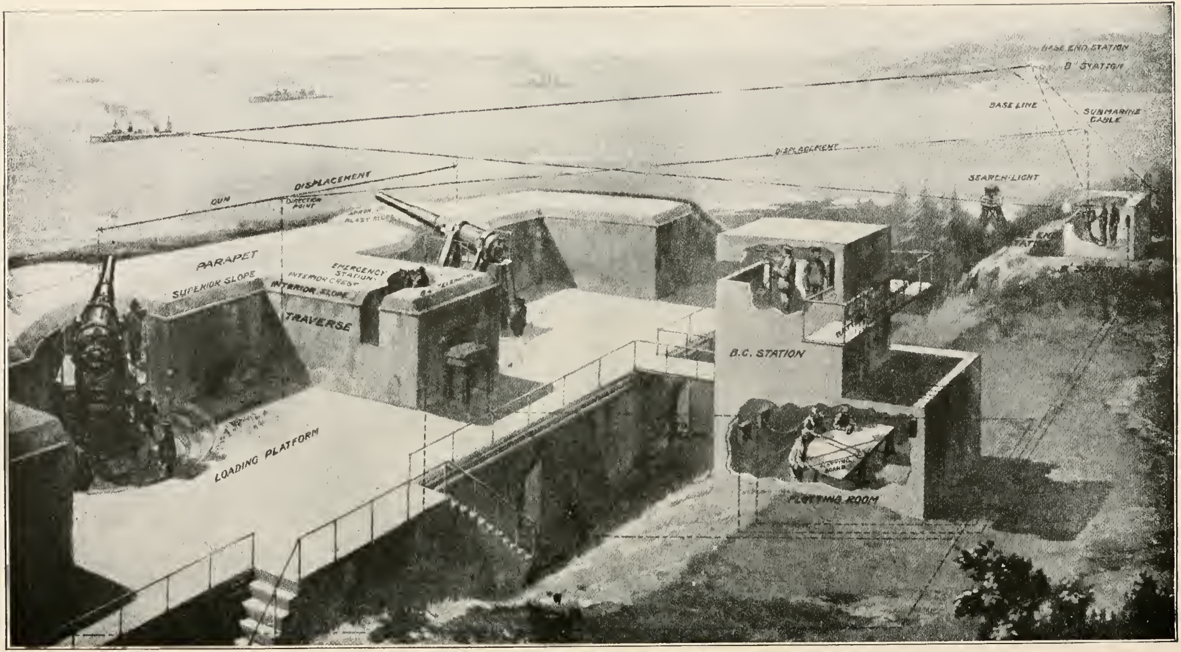
The perfecting of the flying machine has brought into use new and deadly weapons. They are steel arrows, about five inches long and a little thicker than a lead pencil. They are dropped from aeroplanes in batches of 500, a mechanical arrangement spreading them over an area of 200 yards. From a height of 1,500 feet they obtain a terrific speed by the force of gravity, and will penetrate a man's body from his head to his heel. It is reported that they are used by all the airmen of the warring nations.



Palisades in dry ditch in front of parapet.



Section of intrenchment made in stiff soil. The legends designate in military terms the various portions of such an intrenchment.



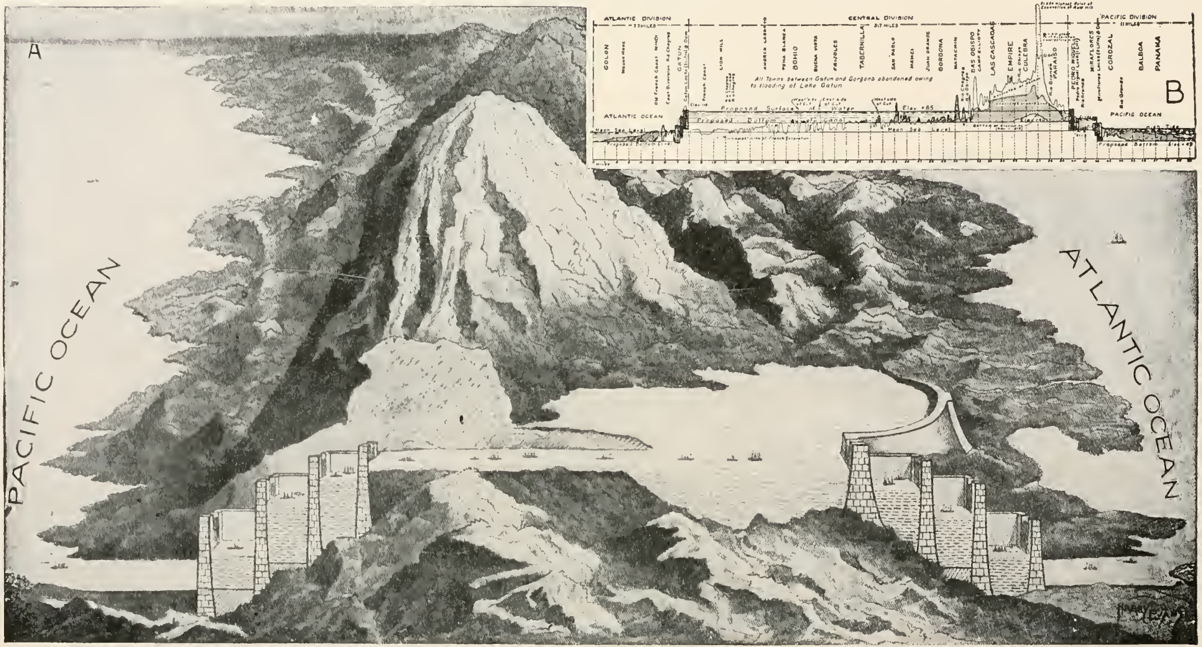
MODERN COAST-DEFENSE: HOW AN UP-TO-DATE SHORE BATTERY WORKS ON MATHEMATICAL LINES AGAINST AN ENEMY'S FLEET

The leading hostile war-ship having been sighted, its position is found by observing the angles the ship makes at two observing-stations, B1 and B2, situated at the end of a common base-line of known length. These angles are telephoned to the plotting-room, where the position of the ship is found. From the plotting-room the proper elevation, etc., is telephoned to the gun. All the fire-control instruments and stations are located at obscure places in the fort reservation, and are amply protected by parapets of earth and concrete. They are connected with each other by underground telephone, telautograph, or speaking-tube. The "predicted range" is sent to the guns, and the "predicted time" is given by a bell.

Book of Engineering and Industry

THE PANAMA CANAL—SEVERING THE TWO AMERICAS
CONQUEST OF THE SEA
BEACONS OF THE SEA
HARNESSING THE WORLD'S GREAT WATERFALLS
UNDERGROUND ENGINEERING
FOOTPATHS IN THE AIR
FOOD BEVERAGES—TEA, COFFEE, CHOCOLATE
MARVELS OF GLASS MAKING

THE WONDERFUL STEPS OF WATER UP WHICH GREAT SHIPS WILL CLIMB



A.—This picture gives a vivid idea of how the new world is cut in two by the Panama Canal, and how the biggest ships climb up the hills and steam right through the Culebra mountain from one ocean to another, making, from point to point, in a few hours a voyage that formerly took many weeks. There are three great locks at each end of the canal, and these work on exactly the same principle as ordinary canal locks, only they are the most wonderful locks the world has ever known.

B.—Profile of canal, showing amount excavated by the French and Americans respectively. The canal consists of the two stretches at sea level and a third stretch supported by locks at an elevation of 85 feet.

SEVERING THE TWO AMERICAS

THE completion of the Panama Canal marks the end of the greatest engineering undertaking in the history of human progress. It was envisioned by men as early as the time of Balboa, the famous discoverer of the Pacific, but it remained for present day enterprise and skill to make it an accomplished fact. More like a story from the Arabian Nights than the story of the work-a-day world, this marvelous stairway of water, separating two continents and uniting two oceans, may well be classed among the new wonders of the world.

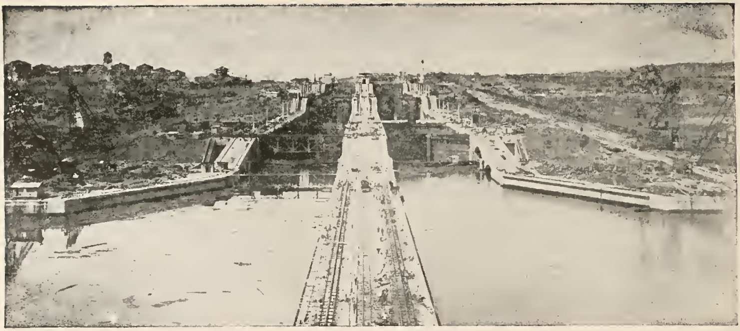
THE FRENCH PANAMA CANAL COMPANY

Though a subject of vision and discussion for upward of four hundred years, no step was taken toward the actual planning of the canal until the year 1876. In that year Columbia granted a concession for the construction of the canal by way of Panama to Lieut. Wyse, an officer in the French army. This concession Lieut. Wyse sold to a group of French financiers, who, because of the prestige he had acquired by reason of his brilliant success at Suez, persuaded Count Ferdinand de Lesseps to join them as chief engineer. De Lesseps went out to the Isthmus in 1879, and, having gone over the ground with his experienced eye, pronounced in favor of the undertaking and determined on the course between Colon and Panama City, over which the United States Government was afterwards to undertake the completion of the canal. Early in 1881 these Frenchmen organized the Panama Canal Co., to own the concessions and carry through the undertaking.

In 1889, after eight years of active work, this company went into bankruptcy, and a new one that succeeded it in 1894 was enabled to resume operations only to an extent sufficient to keep alive its franchise.

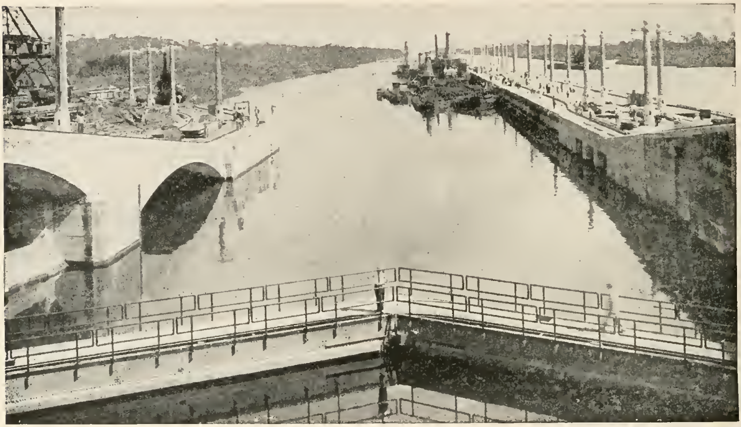
ACQUISITION OF FRANCHISE BY THE UNITED STATES

In 1902, under the administration of President Roosevelt, the Government of the United States, which had become more than ever interested and had had under consideration the construction of the canal through Nicaragua, concluded to take up the work in Panama if satisfactory arrangements could be made with the French company for the acquiring of its rights. It was pending these negotiations in 1903 that Panama declared her separation from Columbia and became an independent republic. On the 28th of November, 1903, the French company having agreed to sell for $40,000,000, the Hay-Bunau-Varilla treaty between the new republic and the United States was signed. It



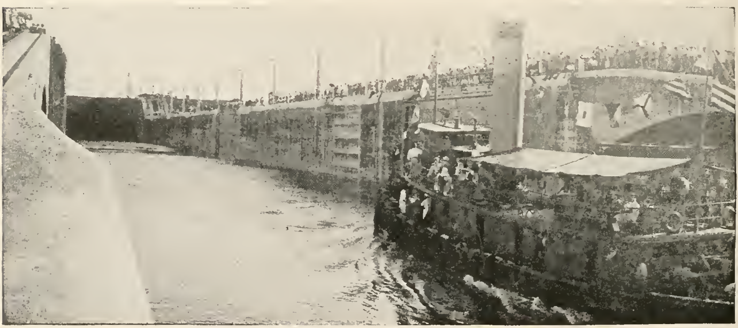
GATUN LOCKS

General view from temporary tower on north end of approach wall. Looking south. Sea gates under pressure



OPERATION OF GATUN LOCKS

Looking north from north gates, showing lower guard gates, dredging fleet in distance and Atlantic entrance to canal



OPERATION OF GATUN LOCKS

First boat through. Tugboat "Gatun" entering lower lock, west chamber Looking south from center wall was promulgated on the 26th of February, 1904. Under its terms, $10,000,000 was paid to the government of Panama for the right of way and an annual rental of $250,000 agreed upon, to begin nine years after date. The United States guaranteed the independence of Panama and secured absolute control over what is now known as the Canal Zone, a strip of land ten miles wide extending from Colon to Panama City, through the center of which runs the course of the great waterway. The French company's franchise and property rights were purchased at the figure stated and the formal transfer to the United States was made on the 4th of May, 1904.

Colonel Goethals the Man and the Occasion

Six days after the promulgation of the treaty President Roosevelt appointed the body known as the Isthmian Canal Commission to have charge of canal construction. The Commission was reorganized at various times and finally the government determined to take over the work itself. In April, 1907, Col. Goethals was appointed Chairman and Chief Engineer, and under his direction this gigantic work has been brought to completion.

Turning in the Waters

On August 31, 1913, a charge of 48,000 pounds of dynamite blew up the so-called Miraflores dike and permitted the waters of the Pacific Ocean to approach the Miraflores locks situated eight and one-half miles inland from the Pacific entrance of the canal. On October 1, a severe earthquake, more marked indeed than the San Francisco trembler, put the great work to the supreme test and at the same time served to throw the population into consternation and distress. Fortunately, not the slightest harm befell the locks, and the critics of the plan as well as the usual small army of prophets of evil, were silenced temporarily at least. The black population returned to its routine labors following a few days of "camp meeting," during the progress of which the welkin resounded with high-pitched lamentations, prayers of many kinds, and unconditional promises to be good in the future. Colonel Goethals and his staff did not hesitate for one moment, but, on the contrary, began on October 1 to turn water into the only remaining dry section of the canal, the Culebra cut. This was accomplished by means of four twenty-four-inch pipes which pierced the Gamboa dike. President Wilson himself applied the finishing touches to this branch of the work when on October 10 he pressed a little pearl button in the city of Washington, which in turn sent an igniting spark some four thousand miles to Gamboa dike, there to tear out two hundred feet of rock and earth and permit the waters of Lake Gatun to rush headlong through Culebra cut as far back as the Cucaracha slide.

The First Boat to Pass the Locks

Gatun locks were operated for the first time on September 26, 1913, when the sea-going tug *Gatun* was passed through the west flight from the Atlantic channel to Gatun Lake. Though various temporary methods were employed in filling the locks with water this was actually the first occasion upon which any of the locks in the entire system were used to pass a vessel from one level to another. The filling of the lower lock was completed about 4:45 p. m., when the sea-gate was opened and the *Gatun* with flags flying and whistle blowing, steamed into the lower lock. The lower operating gates were closed and the tug came to a stop. The process was repeated in the middle lock and at 6:15 p. m., just as dusk was falling, the vessel entered the lock for the last lift. This was accomplished thirty minutes later when the two last gates swung open and the tug passed out into Gatun Lake. The entire passage required an hour and a half.

WONDERS OF ENGINEERING

But when one pauses to remember that this simple operation has taken almost ten years to make possible, at a cost of $375,000,000, and a toll of thousands of lives, a more appreciative feeling comes to the onlooker. Almost 220,000,000 cubic yards of earth and rock have been excavated and 5,000,000 cubic yards of concrete have been poured into the locks, each of which is 1000 feet long and 110 feet wide, and will accommodate a vessel 1000 feet long. As a matter of fact, there are twelve lock chambers, or as they are designated, six twin locks. There are lengthwise culverts eighteen feet in diameter, running through the great lock walls, and it is through these that water is taken in from the upper levels. Smaller lateral culverts run in and under the lock floors and from them the water pours into the lock chambers through great holes. Electric motors operating giant valves are used to control the flow of water in and out of the chambers. Electric "mules" tow vessels through the locks at a maximum and fixed rate of two miles an hour.

The two great engineering problems encountered and solved by the Americans were: the control of the waters of the Chagres River and the cut through the Continental Divide. The first was met by the construction of a huge dam, Gatun dam, one and one-half miles long and one-half mile wide at the bottom across the valley of the Chagres River at Gatun. This resulted in the creation of Lake Gatun over an area of 164 square miles. It covers an area of 64 square miles and the worst flood recorded in the history of the Chagres River would barely raise the surface one foot in nine hours. Smaller dams have been built near Pedro Miguel and Miraflores locks, and like the Gatun structure, they are now overgrown with vegetation and appear to be part of nature's own handiwork. The other difficulty was overcome by the obvious method of drilling the Culebra cut through the Continental Divide in the teeth of the greatest discouragements.

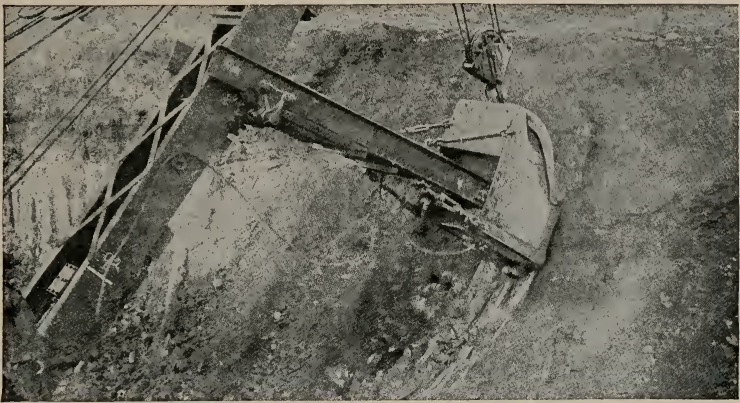
PRODIGIOUS LANDSLIDES

By far the greatest obstacle encountered has been the cut at Culebra. A cut of such great dimensions has never before been attempted, and the rock through which it was made was of a peculiarly intractable nature. But the difficulties of the work have been greatly augmented by the enormous landslides which have been in progress more or less uninterruptedly since the French began to dig. These landslides have necessitated the excavation of 20,000,000 cubic yards of dirt from the waterway.

A TRIP THROUGH THE CANAL

A vessel passing from ocean to ocean will require from ten to twelve hours, depending on the speed maintained in those portions of the canal in which it travels under its own power. Let us take a steamer on the Atlantic side: the starting point will be near the end of Toro breakwater, which extends out two miles as a protection against the destructive northwest winds. Our vessel will steam a distance of seven miles through a channel 500 feet wide to Gatun, where the series of three locks of that name are situated. Along the route to the left (east shore) may be seen the twin cities of

THE GIANT STEAM SHOVEL AT WORK



The most gigantic engineering feat ever undertaken by man was the cutting of the American continent in two by the making of the Panama Canal. The most wonderful tools were used and here we see how the great shovel thrust against an embankment scraped away the earth. The largest raised as much as ten tons at one scoop.

When the shovel was full, it was swung round over a railroad car, the bottom was opened, and the earth fell into the car. One shovel did the work of a hundred men and over one hundred shovels were used on the canal.

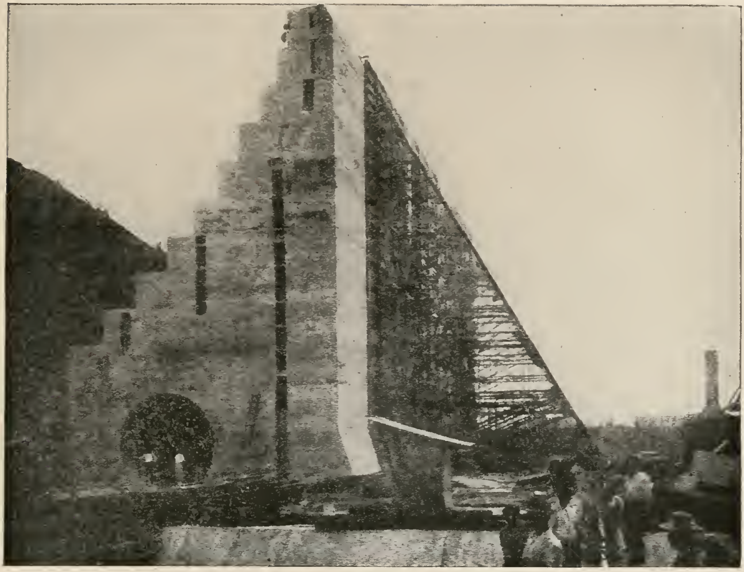
Here is a near view of the earth being pushed off the cars. The machine that did this was a kind of plow that traveled from one end of the train to the other, unloading twenty cars in ten minutes. One unloader did the work of four hundred laborers.

THE BED IN WHICH TWO SEAS MET

The mighty cutting through the Culebra mountain shown here is one of the wonders of the world. The engineers literally moved mountains. Altogether 300,000,000 tons of earth were removed for the canal.

This is another part of the cut through the Culebra mountain. To blast away the rock more than a million cartridges were exploded in a year, and the removal of the material excavated is no less wonderful than the excavation.

WALLS THROUGH WHICH THE SEAS FLOWED



To collect and harness sufficient water a great dam has been built, and by storing flood waters that formerly ran away a lake of 164 square miles, called Gatun Lake, was formed. Here we see a wall of the Gatun locks, the walls being more than half a mile thick at the bottom. The round opening in the wall is the tunnel through which the surplus water will flow. The Gatun dam is the mightiest in the world.

Pedro Miguel Locks in the Panama Canal, showing south end of east chamber and construction of safety and lower gates

Crystobal and Colon with their hospitals, fine new steel-concrete piers, employes' homes, commissary houses and ships from the far corners of the earth. Further on is Mt. Hope, famous for its cemetery and receiving station for all supplies. Both shores are fringed by the myriads of plants and flowers and trees which make up the tropical jungle. Entering the locks the steamer is lifted eighty-five feet to the level of Gatun Lake thirty minutes being spent in each lock. Thence through a lake channel from 500 to 1000 feet wide, it steams twenty-four miles to Bas Obispo, whence the Culebra cut leads through nine miles of excavations to the single lock at Pedro Miguel. The minimum width of this cut is 300 feet. This lock lowers the vessel thirty and a third feet to the 55-foot level of the small artificial lake, Miraflores. Another mile under its own power and the vessel is lowered through two more locks called Miraflores, to the Pacific level, from which point it steams through a 500-foot channel eight and a half miles to deep water in the Pacific. All of which seems simple enough.

What the canal means

What does the Panama Canal mean? What does it mean to the United States, to Latin America, to Europe, to Asia, to Australia, and to all of the world?

These are questions which every one interested in the progress of the world cannot fail to turn over constantly in his mind.

No other great engineering undertaking, not even the construction of the Suez Canal, the building of the transcontinental railways of North America, the construction of the great wall of China, has had any such effect on the power, prestige, commerce, and opportunity of one or of a group of nations as will have the Panama Canal.

For the United States and its twenty sister American Republics the formal opening of the canal will be the solemn inauguration of a great new Pan American era of commerce, friendship, and peace. In separating North from South America with a water channel it will draw them closer together in ties of better acquaintance and larger trade.

Just as a new railroad built through a sparsely settled country between two cities does not begin to do the business at first which comes to it later on through the construction of feeders, the filling up of the country, and the growth of its terminal points, so the Panama Canal, through the extension of old steamship lines, the putting on of new lines and tramp vessels, and the building up of the countries reached by them, will increase its commerce and its shipping with eventual individual benefits to each port within the limit of its influence.

Probably the greatest good to the United States from the canal will result from the cheap, short, and quick route of water communication between its Atlantic, Gulf, and Pacific seaboards.

Simple contrasts in distance

Some simple contrasts in distances between the Panama Canal and the Straits of Magellan will show at a glance what the Panama Canal means in the relations of the Atlantic, Gulf, and Pacific seaboards of the United States. By Magellan, the distance from New York to San Francisco is 13,135 miles; by Panama, 5262 miles, a saving of 7873 miles, or more than twice the distance across the Atlantic Ocean. From New Orleans to San Francisco, by way of Magellan, is 13,551 miles; by way of Panama, 4683 miles, a saving of 8868 miles, or practically a month's steaming of vessels averaging 12 knots an hour. Such figures need no further argument than themselves to illustrate the real significance and meaning of the canal.

While the shortening of the distance between the domestic ports of the United States is, perhaps, the most remarkable and important fact, the saving effected between the ports of the United States and others beyond

COMPARATIVE DISTANCES (IN NAUTICAL MILES) IN THE WORLD'S SEA TRAFFIC AND DIFFERENCE IN DISTANCES VIA PANAMA CANAL AND OTHER PRINCIPAL ROUTES

TO	VIA	FROM					
		New York	New Orleans	Liverpool	Hamburg	Suez	
Seattle	Magellan	13,953	14,369	14,320	14,701	15,397	
	Panama	6,080	5,501	8,654	9,173	10,447	4,063
Distance	saved	7,873	8,868	5,666	5,528	4,950	
San Francisco	Magellan	13,135	13,551	13,502	13,883	14,579	
	Panama	5,262	4,683	7,836	8,355	9,629	3,245
Distance	saved	7,873	8,868	5,666	5,528	4,950	
Honolulu	Magellan	13,312	13,728	13,679	14,060	14,756	
	Panama	6,702	6,123	9,276	9,795	11,069	4,685
Distance	saved	6,610	7,605	4,403	4,265	3,687	
Guayaquil	Magellan	10,215	10,631	10,582	10,963	11,659	
	Panama	2,810	2,231	5,384	5,903	9,192	793
Distance	saved	7,405	8,400	5,198	5,060	2,467	
Callao	Magellan	9,613	10,029	9,980	10,361	11,057	
	Panama	3,363	2,784	5,937	6,456	7,730	1,346
Distance	saved	6,250	7,245	4,043	3,905	3,327	
Valparaiso	Magellan	8,380	8,796	8,747	9,128	9,824	
	Panama	4,633	4,054	7,207	7,726	9,000	2,616
Distance	saved	3,747	4,742	1,540	1,402	824	
Wellington	Magellan	11,344	11,760		13,353	9,694	
	Suez			12,989			
	Panama	8,857	8,272	11,425	11,944	9,205	6,834
Distance	saved	2,493	3,488	1,564	1,409	489	
Melbourne	CapeGoodHope	13,162	14,095		11,845	8,186	
	Suez			11,654			
	Panama	10,392	9,813	12,966	13,452	10,713	8,342
Distance	saved	2,770	4,282	1,312	1,607	2,527	
Manila	Suez	11,589	12,943	9,701	9,892	6,233	
	Panama	11,548	10,969	14,122	14,608	11,869	9,370
Distance	saved	41	1,974	4,421	4,716	5,636	
Hongkong	Suez	11,673	13,031	9,785	9,976	6,317	
	Panama	11,691	11,112	13,957	14,443	11,704	9,173
Distance	saved	18	1,919	4,172	4,467	5,387	
Yokohama	Suez	13,566	14,924	11,678	11,869	8,210	
	Panama	9,798	9,219	12,372	13,858	11,119	7,660
Distance	saved	3,768	5,705	694	1,989	2,909	
Panama		2,017	1,438	4,591	5,110	6,387	

its shores upon the Pacific is almost equally significant and impressive. A steamship bound from New York to Honolulu, using the Panama Canal in preference to the Magellan route, will save 6610 miles; from New York to Wellington, New Zealand, 2493 miles; to Melbourne, Australia, 2770 miles; and to Yokohama, Japan, 3768 miles. All these distances give also a large advantage to the Panama Canal over the Suez Canal route, but there is practically no choice in actual distance between the Panama and Suez routes in the steaming distance from New York to Hong Kong, China, and Manila, the capital of the Philippines.

The saving of the Panama over the Magellan route for vessels running not only from New York, New Orleans, and neighboring ports but from England and northern Europe to the principal ports of the west coast of South America is one of the best illustrations of the value and meaning of the canal. The first northern important port of the Pacific coast of South America is Guayaquil in Ecuador. A steamship bound from New York to Guayaquil going through the canal will be obliged to steam only 2810 miles, instead of 10,215 miles via Magellan, a saving of 7405 miles, or between twenty and thirty days, according to the power of the vessel. The steamship from New Orleans making this journey would save 8400 miles; from Liverpool, 5198 miles; and from Hamburg, 5060 miles. Callao, the principal port of Peru and the next important port south of Guayaquil, via the canal, is only 3363 miles from New York, or equal to about the average distance across the Atlantic Ocean from New York to England. By the Magellan route it is distant, 9613 miles, so that the steamer going from New York to Callao via the canal saves 6250 miles. From New Orleans the distance saved is 7245 miles; from Liverpool, 4443 miles; and from Hamburg, 3905 miles.

Valparaiso, the chief port of Chile, is generally considered the principal terminal point for steamships which will go via the canal to the west coast of South America. Through its harbor, not only is the large trade of Chile reached but to some extent that of the great Argentine Republic, whose capital, Buenos Aires, is connected with Valparaiso by rail. By the canal, Valparaiso, which according to our old ideas seemed far away from New York, is only distant 4633 miles via the Panama Canal. Although it is the nearest port of the west coast to the Straits of Magellan, it is 3747 miles nearer New York via Panama than via Magellan. A vessel from New Orleans to Valparaiso saves via the canal 4742 miles; from Liverpool, 1540 miles; and from Hamburg, 1402 miles.

CURVATURE OF EARTH'S SURFACE

There are two facts not generally appreciated in the matter of distances. On account of the curvature of the earth's surface a vessel en route from Liverpool to the Panama Canal taking the great circle route can by only one extra day's steaming, or a detour of between three and four hundred miles, include New York City as a port of call, enabling it to coal there or get additional cargo. Correspondingly, a vessel en route via Panama to Yokohama, or vice versa, by only a slight detour of less than two days' steaming can include San Diego, Los Angeles, or San Francisco as ports of call for both cargo and coal.

CITY OF PANAMA AND MAP OF THE CANAL ZONE

SCENES IN THE LUCKY LITTLE CITY OF PANAMA

PANAMA RAILROAD STATION

CATHEDRAL PLAZA, DURING A CARNIVAL

THE CANAL ZONE

The Canal Zone, over which the United States exercises all the rights of sovereignty under a treaty with the republic of Panama, boasts an area of 448 square miles. It begins three marine miles from the mean low water mark in each ocean and extends for five miles on each side of the center line of the route of the canal. The cities of Colon and Panama City are excluded from this special sovereignty, except that the United States may enforce sanitary ordinances therein and maintain order in case the Republic of Panama shall at any time not be able to do so.

PANAMA FINANCIALLY INDEPENDENT RICH IN METALS AND AGRICULTURE

Panama is the most independent nation, financially, in the world. It is the only nation which receives interest on money it has loaned instead of paying interest on funds borrowed. The country, vastly rich in resources of mines, fields and sea,—has come into its own—and all because of the canal.

Panama has no bonded debt on which to pay interest. It has invested in gilt-edge mortgages in the United States, $6,000,000, bringing in an income yearly of about 4½ per cent. There is $300,000 on deposit to guarantee the parity of its currency, and since 1913 the United States pays a perpetual yearly rental of $250,000 for the canal. The income from taxation amounts to about $5,000,000 yearly, and there is no army, no navy and no expensive courts to keep up. All money is available for improvements, and Panama is the only nation collecting interest on its own money instead of paying out interest on loans.

THE MARKET BOATS AT LOW TIDE, PANAMA

UNITED STATES BATTLESHIP SQUADRON AT HAMPTON ROADS

CONQUEST OF THE SEA

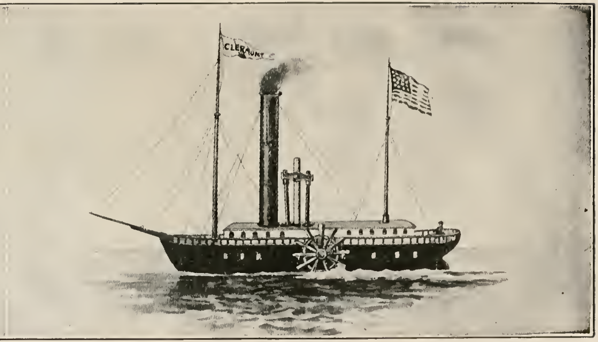
IN no field of enterprise has man achieved more notable progress than in shipbuilding. Today he plows the ocean in mighty vessels towering 100 feet above the waves, measuring more than 900 feet in length, and nearly 100 feet in width, propelled at a speed of from 25 to 28 miles an hour by wonderful and intricate machinery, and possessing in their appointments every form of luxury in the way of convenience and comfort. Indeed, the modern liner is a floating palace as well as a floating city containing a population of between 4000 and 5000 souls. It represents the genius and cunning of the architect, the artist, and the decorator, as well as the highest skill of the shipbuilder and engineer. Its construction demands three years of labor, building and fitting out a modern liner, and an expenditure of between $6,250,000 and $10,000,000.

With no ships the sea would be a source of horror to us. It would be a fearful void, shutting us out from communication with other parts of the world. And that is just what the sea was to men before they learned the art of shipbuilding and navigation. By a series of grand schemes men have changed all this. There was the gradual building of great ships; there was the making of accurate instruments by which men could tell at any moment of the day or night their exact position at sea, no matter how far they went; there was the application of steam to the purpose of the ship; and there was the laying of the ocean cables.

These things accomplished, the sea remained no longer an enemy. The ocean became a roadway, leading to all parts of the world. Storm and tempest, fogs and hidden rocks, still cause disaster, it is true, but the accidents are rare, considering the enormous number of ships there are. The sea has become one of our best friends.

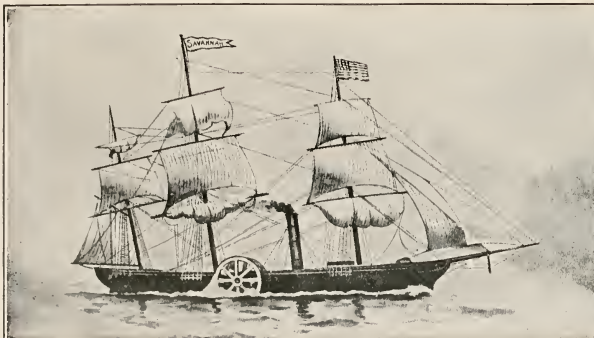
"JOHN FITCH"

This is positively the first steamboat ever built. The above illustration shows the boat as it appeared on the Delaware River, opposite Philadelphia in 1786.



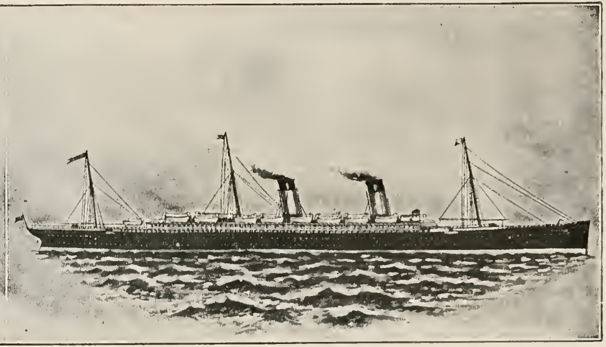
THE "CLERMONT"

Made the trip from N. Y. to Albany, September, 1807. The "John Fitch" was built and operated on the Delaware River 21 years before the Clermont was completed.



STEAMSHIP "SAVANNAH"

The first steamship to cross the Atlantic Ocean. Sailed from Savannah, Georgia, on May 20th, 1819; arrived at Liverpool, England, June 11th, 1819.



THE "OCEANIC"

Completed in 1901 and called the "Queen of the Ocean," is 704 feet in length, or 25 feet longer than the famous "Great Eastern," hitherto longest vessel ever built.

And all this wonderful change in our affairs we owe to a very small number of men. It will be enough for our purpose if we glance briefly at the careers of the chief figures in these revolutions in the history of the world.

Every time that some great change has been proposed for the benefit of mankind, people with power and influence, who ought to have given their encouragement and support, have always been among the first to say: "It can't be done," and "It shan't be done." That is just what happened concerning the steamship and the ocean telegraph. Take first the steamship. No invention ever had a harder struggle for life. Fate and men both seemed against it.

THE MAN WHO FIRST MADE A MACHINE DRIVE A BOAT THROUGH WATER

The Spaniards say that a countryman of theirs, named Blasco de Gary, who lived in the sixteenth century, made a model steamboat in 1543. Every country is anxious to claim the honor of an invention, if the invention has proved a success.

A century later, Denis Papin, a famous Frenchman, appeared on the scene. He was a physician, born at Blois in 1647, and he died in England in 1712. Frenchmen declare that he invented the steam-engine and steam navigation, and in many books his name is given as having achieved that result. But that is wrong. He was a man of splendid brain, but his thoughts did not turn to the making of a true steam-engine as we know it. What he invented was an engine worked not really by expanding steam, but by atmospheric pressure. His idea was a brilliant one, and it led to great things in the hands of Newcomen, Brindley, and Smeaton. We must remember that it was not the true steam-engine; but as his engine, such as it was, was fitted to a model boat and drove the boat through the water, Papin well deserves his place in the gallery of heroes who brought about steam navigation.

TWO GREAT INVENTORS WHO WERE RUINED BY THE FRENCH REVOLUTION

Many names appear for a little time upon the page of the history of this invention. One of them, Jonathan Hulls, patented a sort of steamboat in England in 1737, but years were to pass before anything practical was done. More men crowded to the task, and we find several skilled inventors working in rivalry at the same time. One of these was the unfortunate Marquis de Jouffroy, who, born in France in 1751, set himself, at 26, the task of driving a boat by steam. He adopted Papin's idea, and in eight years made three successful boats. The first was 40 feet in length; but it was the third which is said to have been the first real steamboat. He might have gone on to complete success, but the French Revolution drove him, an exile from his country, to America. When he returned to France, he was too late; others had seized his ideas and begun to reap the honors which should have been his. He died in 1832.

At about this time two American engineers, named James Rumsey and John Fitch, were making experiments. Rumsey is of importance to us as being the man who first turned the attention of Robert Fulton to the subject. Fitch came into prominence in the American Revolution, acting as gunsmith for the Americans, who were fighting for their liberty against the British. His first model steamship was made in 1785, but five years later he built a proper vessel, with paddle-wheels at the sides. He went to France just as Jouffroy was leaving, and, like Jouffroy, was ruined by the

Revolution. It is said that while he was there his plans were shown to Fulton. Anyhow, he returned to America starving, and killed himself.

THE MAN WHO CAME TO PAINT PICTURES BUT MADE A STEAMBOAT

It was for something quite different from shipbuilding that Robert Fulton went to England. He was a painter of portraits, born in Pennsylvania in 1765, but set out for England in 1786, in order that he might study this art under Sir Benjamin West. He became acquainted with Rumsey, who had also gone to England earlier, and, after discussing inventions with him, gave up all thought of painting. Fulton's brain teemed with ideas. He invented things for the improvement of canals, for cutting and polishing marble, for twisting rope, for iron bridges, for spinning flax, for dredging rivers, and for making boats go under water and blow up ships. But the great work of his life was done for the steamship.

In 1802 he built a steamship, but its engine was so heavy that it fell through the bottom of the vessel into the River Seine, in France, where he was trying it. He did not lose heart, but recovered the engine and built it into a stronger boat. This he made to go, but it was too slow to be successful. Going back to England, he prepared plans and had an engine built by Boulton and Watt. Then he came to America and left the engine to be brought over, packed up in a ship. When it arrived, he set to work to put it together. His story, told in his own words, gives us an excellent idea of the hard lot of the inventor of those times.

ROBERT FULTON'S FIRST STEAMER, AND THE SCOFFING OF STUPID MEN

"When I was building my first steamer in New York," he wrote, "the work was reviewed by the public either with carelessness or contempt, as a useless scheme. My friends, indeed, were civil, but they were shy. As I had occasion to pass daily to and from the building yard while my boat was in progress, I often loitered unknown near idle groups of strangers, and heard them scoff and sneer and ridicule. Never did a single encouraging remark, a bright hope, a warm wish, cross my path. My work was always spoken of as Fulton's Folly."

But at last the ship was built, and set out with passengers for a trial trip. The vessel moved off, went a little way, then stopped. Everybody except Fulton thought that this was the end—that he had failed, as they all had expected. But he went below and soon put right some trifling mishap, and the boat steamed away, while people were saying: "I told you it would be so; a foolish scheme; I wish we were safely out of it." The vessel went its way, a journey of 150 miles in 32 hours. Fulton was delighted, but his friends still doubted; they thought that the vessel would never be able to get back to New York, and that if it did it could never make another trip. No wonder he felt discouraged. He himself wondered if such a voyage could be repeated, and if it could, whether it was of any value.

WHY ONE OF THE EARLY STEAMBOATS WAS ALLOWED TO FALL TO PIECES

Fulton was the first man, therefore, to make steam navigation what we call a commercial success. Fitch had shown that something of the sort could be done, but Fulton profited by Fitch's experience and by that of Jouffroy. He died in 1815, but not until he had built several other boats.

Fulton's successful steamer was launched in 1807. Nineteen years earlier a successful steamer had been launched in Scotland, but this was not a commercial success. It was built by William Symington, a Scotch mechanic, who was born in 1763, and died in 1831. He first of all built a steam-engine to run on the roads, then carried out the building of the steamship for a thoughtful Scotsman named William Miller. Symington's vessel for Miller was succeeded by another which he built for Lord Dundas. It was launched on the Forth and Clyde Canal, and, without any trouble towed two barges, weighing together 140 tons, a distance of 20 miles against a powerful wind. This was still five years earlier than Fulton's success. But what happened? The owners of the canal said that the steamer would create such a current that it would wash away the banks of the canal, and so this fine steamer was run aground and allowed slowly to fall to pieces on the bank of the canal. Fulton saw this vessel, and doubtless gained a hint or two from it.

A POOR MAN WHO CONFOUNDED THE WISDOM OF THE WISE

But Symington's work was not all wasted. One of the men employed in making the woodwork of his first vessel was Henry Bell, the son of poor Scottish parents. Born in 1767, he followed first one trade and then another, and seemed unlikely to do any good until he was brought face to face with the problems which the luckless Symington was trying to solve. Symington's experiments convinced Bell that success might yet be gained with steam-vessels, and for the next thirteen years he gave all his thoughts to the plan.

We hear of him in 1800 trying to make the British Government believe in the possibility of the scheme, but he was unsuccessful. How could he hope to succeed in official circles when one of the greatest and best men of the day—Sir Joseph Banks, president of the Royal Society—could say to all proposals for vessels driven by steam-engines: "A very pretty plan, but there is just one point overlooked—that the steam-engine requires a firm basis on which to work." Talented man though he was, Banks, himself overlooked one point, that even though it floated on water, the hull of a ship does give the firm basis the steam-engine requires. Bell gave up hope of encouragement from the Government, and when he had managed to get some money, he set to work in 1811 and had a little steamship of his own built on the Clyde.

HOW SCOTTISH INVENTORS AND ENGINEERS LED THE WAY WITH STEAMBOATS

The ship was called the *Comet*, and was launched in January, 1812, beginning at once to carry freight and passengers on the Clyde. Great was the terror that it created among ignorant people. People thought, as they saw it puffing along, snorting sparks and smoke, and going against the wind and the tide, that it was some evil monster. When it approached the shore to pull up, they ran away and hid themselves like savages in some primeval land.

News of the *Comet's* success soon spread abroad, and in 1813, the first of the Thames steamers were run by a man named Dawson, while a courageous man named Lawrence, of Bristol, sent up a steamer from his native city to carry the people of London up and down their great river. The opposition of the Thames boatmen proved too much for Lawrence, and his vessel had to return to the River Severn. But the steamship industry was now fairly founded, in spite of the "wise" men and the Government; and many ships were built on the Clyde to run between Glasgow and Liverpool and other ports.

THE FIRST CROSSING OF THE ATLANTIC OCEAN BY STEAM AND SAILS

From this time forth there was no more opposition to the steamship as a means of sea passage. The next important step was its first voyage across the Atlantic. This was made by an American ship called the *Savannah*, but it did not steam all the way. It was built as a sailing ship by Francis Fickett, of New York, in 1818; but it was decided afterwards to fit it up with a steam-engine. This was done, and it set sail for England from Savannah on May 24, 1819, reaching Liverpool twenty-seven days after.

The greater part of the distance had been covered by the help of sails, steam having been used only for eighty hours. The *Savannah* returned to America and was not considered useful, for its engine was taken out and it depended until it was wrecked, upon its sails. Therefore, although America rightly claims to have sent the first steamship across the Atlantic, we must remember that it sailed for the greater part of the voyage, and steamed only a little now and then, about one hour's steaming for eight hours' sailing.

HOW THE REAL STEAMSHIPS REACHED NEW YORK ON ONE DAY

The first crossing of the Atlantic by a real steamship was completed in 1838, when, on the same day, two English vessels steamed into New York. They were the *Great Western* —a steamship built by Sir Isambard Kingdom Brunel and a smaller vessel, called the *Sirius*. The *Sirius* had started from England four days ahead of the *Great Western*, but the *Great Western*, being bigger and stronger, nearly caught up, and the *Sirius*, reached New York only a few hours ahead. The journey had taken the *Sirius* eighteen days, and the *Great Western* only fourteen, instead of the month which a sailing ship required.

The steamboat was now a success. There was a long fight between rival sides to get the screw propeller used for driving ships instead of the old wheels at the sides called paddle-wheels, but in the end the screw won for all but smooth waters. Similar doubt had to be overcome before the iron ship was built to take the place of wood. Still later there has come another change in the method of driving the ship. The new plan is called the steam-turbine. With his new method of driving a vessel we have bigger steamers than ever.

The monster ocean liners that now ply between the great ports of the world are almost universally of the turbine type.

BUILDING A BIG, MODERN OCEAN LINER

IT is no exaggeration to say that there is nothing that man fashions today that calls for more skill, ingenuity, forethought, and judgment than the designing and building of a large ship. Be it a great liner that will carry thousands of passengers across the ocean at express speed, in spacious and comfortable saloons, or a mighty battleship with an array of formidable guns, all the knowledge, craft, and cunning that the modern shipwright can display will be needed in the evolving of the vessel. From the time the ship is planned in the drawing loft, till she takes the water at her launching, the brains of learned mathematicians, assisted by the might of complicated and wonderful machinery, and the labor of an army of skilled artisans, have been in constant requisition.

For this reason there is no place so bewildering and fascinating as a modern shipbuilding yard. First there are the building berths. These berths

FROM THE CARAVEL OF COLUMBUS TO THE "IMPERATOR" may be inclosed by neat, steel latticework walls, or be entirely open. Here the hulls are built up, piece by piece, amid an ever-growing forest of scaffolding. From the overhead girders, that span the site, run cranes that pick up heavy steel plates and beams, weighing many tons, as if they were mere toys, and lift them into the desired position.

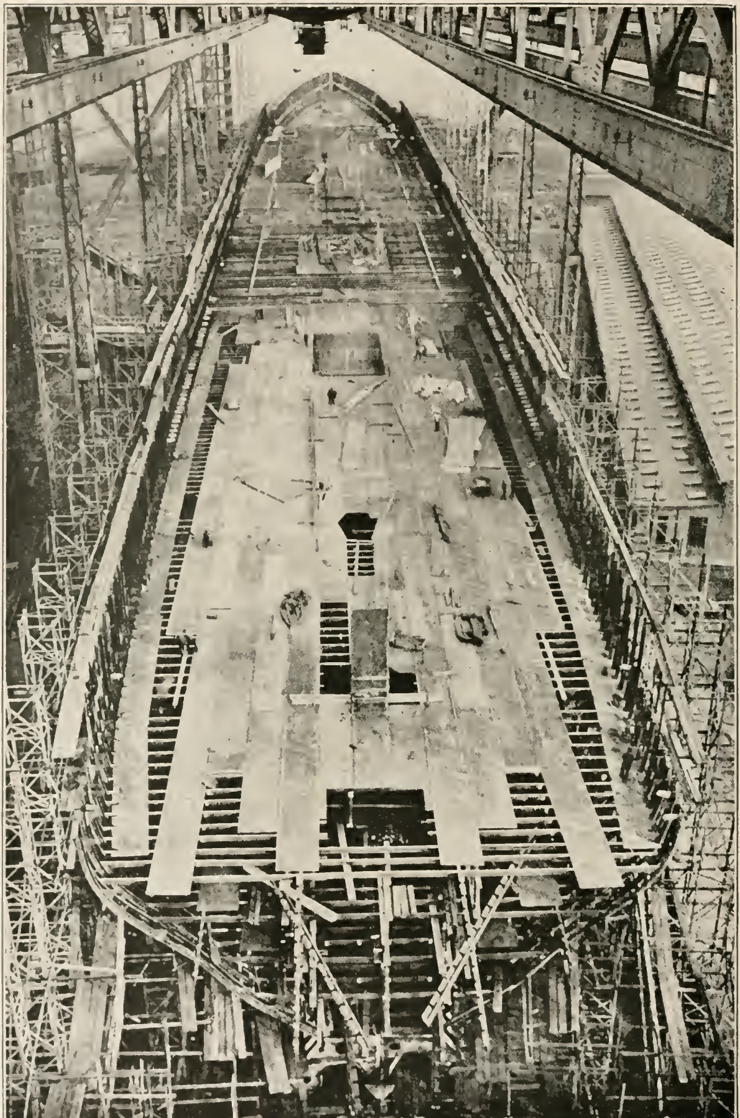
Indeed, all the marvels of machinery are here, driven by steam, electricity, compressed air and water. There are the great presses that bend the steel plates into the desired shape and form; machines that punch holes by the score in them, for the rivets, as easily as you can stick a knife through a piece of paper, while others bite large holes in the hard steel, or reduce the size of the plates by literally slicing off a piece, as deftly and as easily as you could carve a slice off a loaf of bread. Above all, there is the wonderful activity, the constant clang of the riveters' hammers, the snorting of many engines, the glow of furnaces, the rattle of heavy chains, the shouts of the foremen, the toiling mass of humanity, all creating an ordered chaos the like of which can be found nowhere but at those busy yards by the riverbanks where great ships are born.

Naturally, the men in the yard cannot start upon the ship till it has been planned. This is the work of the draughtsmen, and at all the big yards there is what is termed a drawing or mold loft, an immense room, so large that designs can be made to the actual scale of the vessel. This is necessary if the ship is larger than any existing vessel or of a different type from what the builder has turned out before. In that case the draughtsman, taking the floor of his room as an immense blackboard, chalks out in mighty lines all the girders, frames beams and plates. Everything, down to the rivets and rivet-holes, is drawn full size. From these great drawings the working plans are prepared. Then in an immense floor of pine-wood, called the "scrieve-board," the body plan of the ship is cut, from which wooden models are made of her outlines.

From these plans the steel of which the ship is to be built is ordered, as well as all other necessary material. Meanwhile the berth is got ready, and, if the ship is a large one, attention has to be paid to the floor. Before the keel of the *Mauretania* was laid, some 16,000 piles of timber, 13 inches square, and averaging from 30 to 35 feet in length, were driven into the ground. Along the top of these were laid great beams, and on them again a complete floor of thick plates. Much the same procedure was done in the Vulcan yards in Germany, before work was begun on the building of the Hamburg-American liner *Vaterland*, of which we show several illustrations. This vessel is the longest and largest of liners. It is 950 feet long, 100 feet in breadth, and has a tonnage of some 56,000.

Now commences the erection of the hull, which is, in essence, a steel box of curious design. Down the center of the floor are placed portable balks of wood forming piles from 4 to 5 feet high, and known as keel blocks. It is upon these that the keel of the ship is laid. It is a girder of the strongest kind, as it needs to be, seeing that at one moment it may be in the trough of a wave, deeply immersed fore and aft only, and the next riding on its crest with bow and stern almost out of the water. It has, too, to withstand the terrific blows of ocean billows, which tend to bend it sideways.

The strength of the ship lies in this keel and the center girder running



VIEW OF THE "VATERLAND" UNDER CONSTRUCTION

At the moment this is the longest and largest of liners. It is 950 feet long, 100 feet in breadth, and has a tonnage of 56,000.

from one end of the ship to the other. In the case of the *Vaterland* this center girder, immediately above the keel plate, is 6 feet high, and 1½ inches thick. On either side are other girders, running parallel to it, and from these, at various intervals on both sides, spring the ribs or frames, which curve upwards, and to which the plates that form the sides of the ship are fastened. The ribs are held in place by horizontal rafters or beams that carry the decks.

In the case of the modern liner it is now built with an inner skin. That is to say, there are virtually two hulls, one within the other, carried well up above the water-line. The vessel is also provided with a double bottom, while, as an additional precaution, in case of injury by collision that part of the vessel below the water-line is divided into water-tight compartments.

The recently launched *Imperator* is almost one-fifth of a mile long. Her beam of 98 feet compares favorably with the width of a city street.

She carries five anchors, the main one weighing 12 tons, the combined weight of the five anchors and chains being 217 tons. The cargo of many a small steamer is not much larger.

The vessel has a height of 96 feet, her great sides being built upon 327 steel ribs on either side, each weighing over a ton. The weight of the steel plates, angles, profiles, and the like totals 260 tons. More than 2,000,000 steel rivets were used in her construction, each weighing 11 lbs. Because of her great size her decks are particularly imposing. Two of her three broad decks are partially enclosed. The promenades vary in width from 16 to 23 feet, while the circuit of the deck is equal to a walk of five ordinary city streets.

Like the German leviathan, the *Olympic*, *Mauretania*, and other liners of recent construction are marvelously rich in luxurious appointments. The ocean traveler of today is pampered by the provision of electric elevators, swimming baths, palm gardens, restaurants, cafes, and self-contained flats. For instance, one of these vessels boasts of a restaurant under the management of the Ritz-Carlton Hotel, where meals are served *a la carte* at any hour. There are, in addition, a grill-room, tea-room, veranda cafe, and a number of ladies' sitting-rooms, a palm garden, and a superbly appointed ball-room, as well as a stage for theatrical performances and concerts.

The smoking room of this wonderful vessel is a beautiful saloon of the Tudor period. It has a large open fireplace, the red brickwork over which realistically reproduces that of the sixteenth century. The bricks in question came from a Buckinghamshire cottage of the Tudor period, which was demolished for the purpose. The ball-room is undoubtedly one of the greatest innovations of the ship. It is 72 feet long, 58 feet wide, and 18 feet high; the floor is of parquet, which, when not being used for dancing, is covered with a carpet; the walls are decorated with costly old Gobelin tapestry, and have bow windows 10 feet high on either side. It has been constructed with no pillars visibly supporting it. The scheme of decoration is Louis XV. Another unique feature of the ship is the two self-contained flats, comprising drawing-room and veranda, with large windows opening out over the sea, dining-room, two bed-rooms, two bath-rooms, dressing-room, box-room, and pantry. These are among the most expensive dwelling places in the world, for the occupants pay a fare of from $2500 to $5000 for a single short voyage.

MAIDEN VOYAGE OF THE "IMPERATOR"

HAMBURG POPULACE WITNESSING THE STEAMER'S DEPARTURE FROM THE PORT OF HAMBURG

"IMPERATOR" ARRIVING IN NEW YORK HARBOR, SHOWING THE OUTLINES OF ITS IMMENSE HULK AGAINST THE CITY'S SKYSCRAPERS

THE FLOATING RITZ-CARLTON

On the "Imperator" there is a restaurant under the management of the Ritz-Carlton Hotel, where meals are served á la carte at any hour.

There seems no end to the money that ship-owners must lavish on their vessels today to attract the custom of the capricious millionaire voyageur. On one ship the Roman bath, with its decorative Pompeian pillars and ornamental cascades of running water, is a masterpiece. The swimming pool has been built after the designs of the ancient Romans. The total length of the bath is 65 feet, the width 41 feet, and the greatest depth of water 7 feet. There are also electric, Turkish, and steam-baths, massage apparatus, and hair-dressing saloons with the most modern equipments, as well as a splendid gymnasium containing everything to satisfy the sportsman's most exacting requirements. Other features include a running track, a sweet shop, a florist's shop, and a photographer's dark room.

The first class and main dining room is a spacious and beautifully decorated saloon, 98 feet wide and 25 feet high, capable of seating 700 persons. All told, the ship can accommodate 720 first, 600 second, 900 third, and 1800 steerage passengers, besides the crew, which totals 1180 hands, giving a total of 5200 souls. As she is capable of performing some fifteen round trips per annum, and the passage money alone per voyage may amount to $400,000 it will be seen that the owners handle a sufficient income from the passengers' fares to make the consideration of their comfort eminently worth while.

It is difficult to realize what it means for the population of a town to go afloat in one huge vessel. But for the perfect organization now in vogue it would be impossible to feed them.

For a seven days' voyage between Hamburg and New York a single ship takes on board 25 tons of fresh meat, 48,000 eggs, and 60 tons of potatoes. The larder also contains 14 tons of fresh vegetables and 6000 tins of canned vegetables. Besides, there are over five tons of fowl and game, and 4½ tons of fish and shell-fish, 800 lbs. of mushrooms, and 4000 cans of preserved fruits. No less than 12,500 quarts of milk and cream, 400 lbs. of cheese, 500 lbs. of chocolate and cocoa, and 7000 lbs. of coffee are also consumed between shore and shore.

THE WONDERS OF A BATTLESHIP

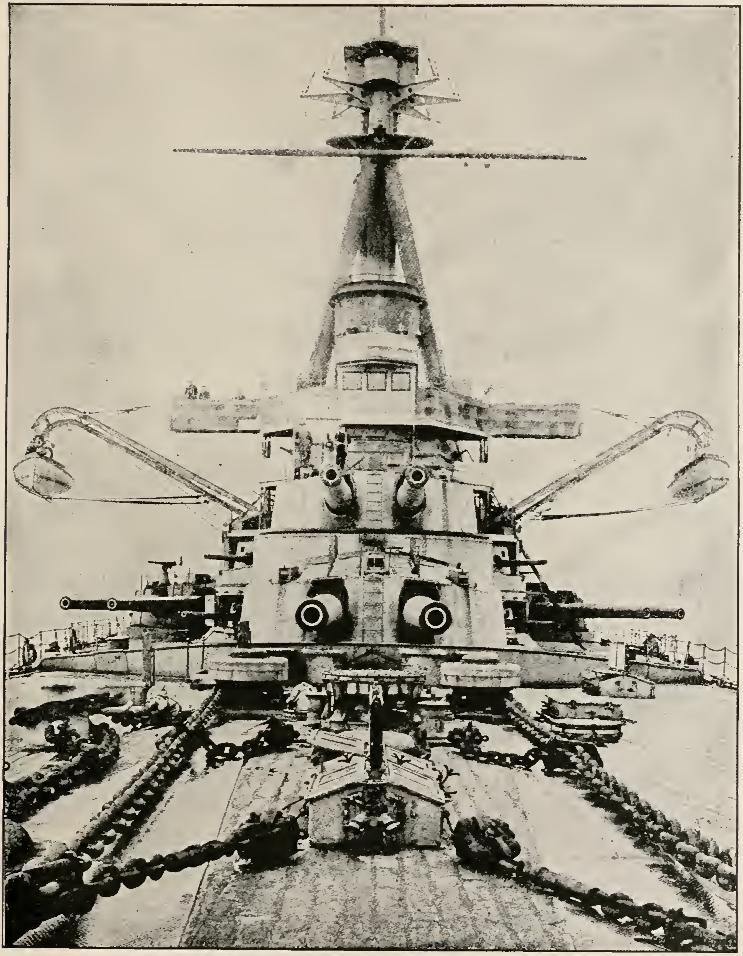
THE modern battleship stands forth as one of the greatest wonders of man's toil and ingenuity. Into a vast whole enter in one way or another all the metals from the roughest iron to pure gold, all the woods from the commonest deal to the most expensive oaks and mahogany, and all the fabrics from canvas to silk, and, more important still, labor that costs most of all.

To take a peep at one of these monsters is to enter a world that is practically unknown to the landsman.

A POPULATION OF 1000 MEN

Step aboard; note the spacious deck, the crowd of seamen who are part of the population of close upon one thousand men, and, above all, observe the grim guns that are the greatest power of this monster ship. These guns are all on the center or keel line of the ship, so that each can fire at almost any angle and have a big sweep of the horizon. In all the latest and greatest ships the guns are super-imposed, that is, the guns in the second turret from the bow and the second turret from the stern fire over the turrets of the forward and after guns. This means that, in chase, four guns can be brought to bear on the enemy ahead.

Now climb through the small aperture that forms the entrance doors to these barbettes and get inside, shut from the outside world by twelve inches of the hardest steel that modern methods can produce. Here is a busy space, populated by less than a score of men who have chained to their will two mighty weapons, each capable of throwing a projectile with deadly accuracy to a distance of eight miles, and with a tremendous bursting charge and shell of 1400 lb. filled with the latest form of chemical explosive. The officer commanding the turret sits on his tiny seat out of the way; a small tube not unlike the periscope of a submarine passes through the hood of the turret and conveys the scene outside to his eye. Before him are telephones and dials that speak to him in a strange language which he understands. High above his head are the range-finders in the control top, perched dizzily at the apex of the tripod mast; provided with delicate and intricate instruments, they are able to detect the range to a nicety. The information thus gleaned by their superior range of vision is telephoned and signaled by electricity to the captain of the turret. Either by hydraulic or electrical power the shell is brought from the shell room right down in the bowels of the ship on a miniature elevator. When this tray, with its death-dealing burden, comes opposite the breech of the gun, which is automatically opened, a rammer drives the shell home, and, in a matter of seconds, the explosive charge follows. The breech clangs and locks by the same movement, the electric contact is connected, and the gun ready for firing. When all is ready, it is the simple pull of a gleaming pistol



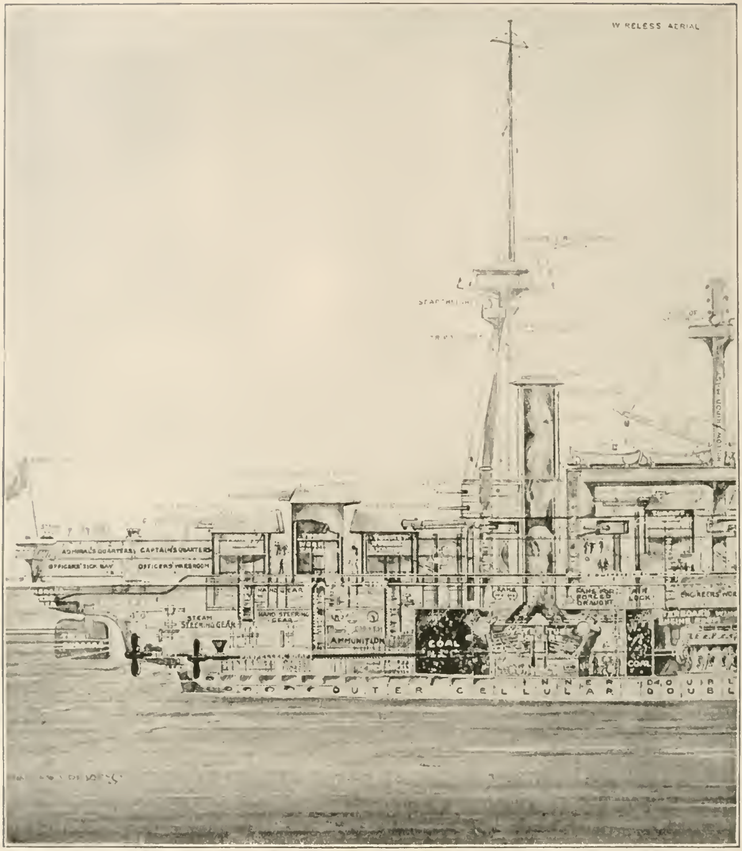
THE BULL-DOG'S TEETH

The photo shows the guns mounted complete and ready for service on board a Dreadnought. Since the firing of 200 rounds, each passing through the barrel in one-fortieth of a second may wear out the A tube of a big gun, its actual working life may be no more than 5 seconds.

trigger that sends the great shell hurtling through space. While it fills the air with thunderous sounds, the blast is already cleaning the gun for the next round.

THE WORKING CHAMBER

Once more clamber through the manhole, leave the gunhouse, and give a glance at the working chamber immediately below it, wherein is the

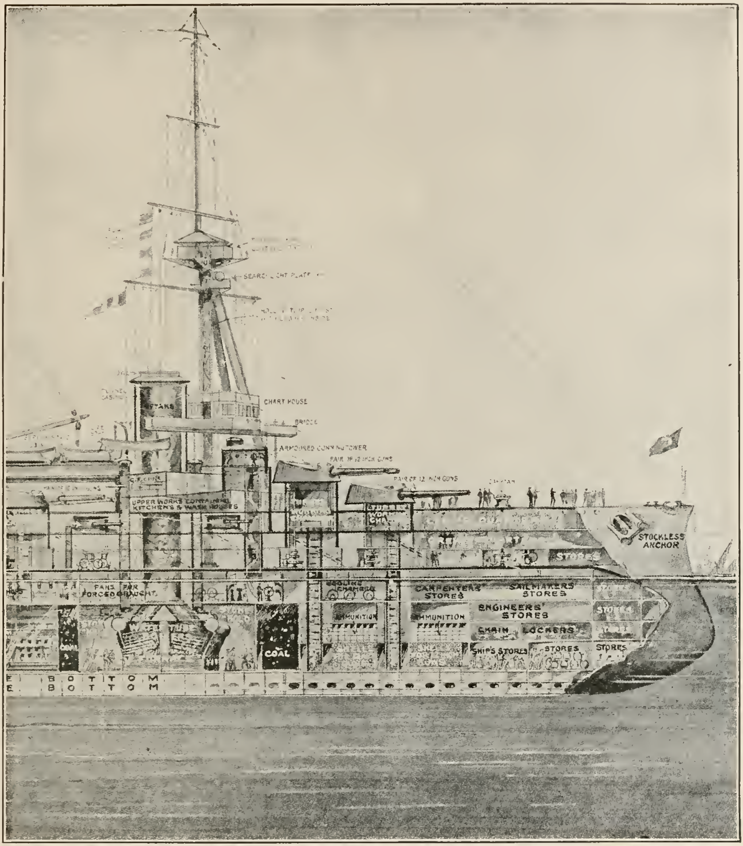


SECTION SHOWING THE INTERIOR

This sectional view of the very powerful "Rio de Janeiro," bought by Turkey from Brazil while still under completion at her speed is 22 knots; her length is 632 feet. She carries fourteen 12-inch and

swash-plate engine that turns the great turret in any direction desired. So wonderful is the gearing that it can rotate the turntable at a fast speed of one revolution in one minute, or at a slow speed of one revolution in ten hours. Other machines are here to work the ammunition hoists, that pass in trunks through this chamber down to the magazine and shell rooms.

On the latest and greatest ships there are five of these great gun-houses, all exactly alike, all manned by an equally alert crew, and all a mass of gleaming, business-like steel. In addition to this the vessel will carry a secondary battery, consisting of quick-firing guns for repelling torpedo boat attack. The majority of new vessels are armed with the 4-inch



OF A DREADNOUGHT AT A GLANCE

the Elswick Yard, makes clear all the details described in this article. The "Rio de Janeiro's" displacement is 27,500 tons; twenty 6-inch guns. Her complement of crews should number 1000 men.

weapon, weighing 26 cwt., and able to send a shell clear through an on-rushing torpedo-boat 1½ miles away. In later ships the 6-inch gun, a new and wonderful weapon, is mounted; this is necessitated by the rapidly increasing size of modern torpedo craft.

Leave the artillery, which is the chief item (for is not a battleship simply intended to act as a floating platform for guns?), and turn to those dim regions far below the armor belt, down below the water line, an inferno of heat and oily smells, where work the "black gang." The modern fighting ship of the speedy battle-cruiser type will have as many as 48 great water-tube boilers, which are roaring boxes of blistering heat when the vessel is steaming hard. There is the continuous clang of the shovel, there is the intermittent search-like glow as furnace doors are opened to examine the fires or add more fuel; there are the oil burners with their pump room above, with engine, pumps, filters, and heaters, and with tanks below in the double bottom to aid the coal with oil should the Admiral suddenly call for speed. There is the roar of a score of draught fans sucking down the necessary air, and along the broadside runs, most wonderful of all, a miniature colliery in full working order, where can be found dim human forms working by the light of Davy lamps, while the great fabric thunders through the riven seas.

Visit yet another quarter where the Chief Engineer holds sway. Here is another domain of oil-smelling heat, with walls lined with miles of steel and copper mains, some gleamingly bright, while others are asbestos covered. Over all rules a clean-shaven officer, and under him are various grades of artificers. Everywhere are dials, and, in different compartments, the vast turbines that rotate the propellers and push the 27,000 tons of metal, wood, and men through the whistling seas.

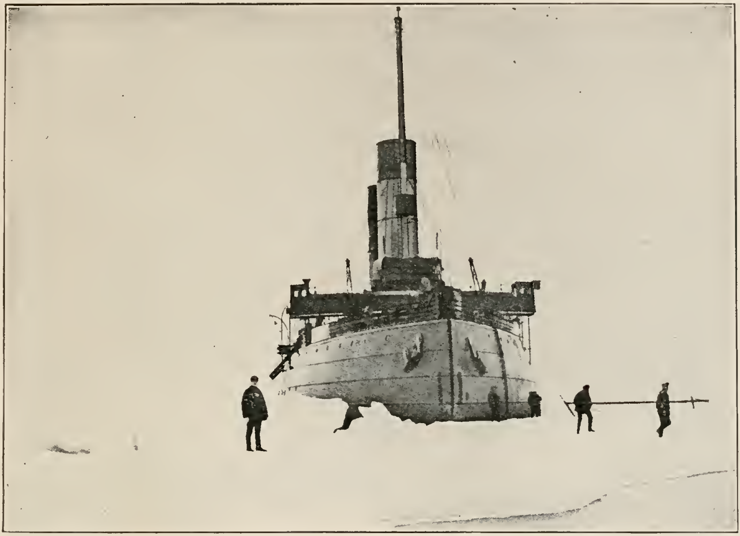
Climb to the bridge, small in size, but lofty and airy. If it be day the panorama of the ship is below you; at your back a great fore funnel, big enough to admit a motor-bus, sends a gentle brown cloud into the sky. Aft this are the boats and pinnaces, the great tripod mast with the fire control and director boxes high above, and the aerials of the wireless telegraphy higher still. All the battle squadron are spread out ahead and astern; all the great ships are seething with life each has its thousand souls, each has its throbbing steel heart, and its gigantic teeth sticking menacingly from the turrets. Each, by means of flags and balls is telling the other strange truths of speed while the officer in command, pacing the bridge, and the stolid quarter-master at the puny wheel (that steers so vast a ship by the aid of steam) keep a clear eye on the nest ahead. As it drops a little we drop also; the engine speed is up and down, changing from minute to minute. If it be dark, a great beam of light may sweep up from over the horizon, and one of our searchlights answers back by a beam that, in fine clear weather, can be seen a dozen or more miles away.

Such is a fighting ship, great and grim, built only to protect us from our foes. In most cases it is built, it lives its short twenty odd years of life, and finally goes to the shipbreaker without ever firing a single gun in anger.

STRONGEST SHIP IN THE WORLD

UNIQUE among boats is the Russian ice-breaker, *Ermack*. On account of its peculiar formation and design it can claim to be the strongest vessel afloat. Indeed, its designers declare that if it were lying on its beam ends alongside a quay 300 feet long, at each end of which there was a giant crane with a lifting capacity of 4000 tons, and these two got hold of it and lifted it clear out of the water, it would hang between them as rigid as a bar of steel. If the same test were applied to a Dreadnought, or any other battleship, it would crumple up by its own weight.

This unique example of the shipbuilders' art is nothing less than a hull of steel 305 feet long, 71 feet broad, 42 feet 6 inches deep, having a displacement of 8000 tons, and driven by the concentrated energy of 12,000 horsepower. It is a double ship from end to end, and its two skins are so con-



THE RUSSIAN ICE BREAKER "ERMACK"

This unique example of the shipbuilders' art consists of a hull of steel 305 feet long, 71 feet broad, 42½ feet deep, having a displacement of 8000 tons and driven by the concentrated energy of 12,000 horse-power. Every winter, while engaged in keeping the Baltic ports open, she is called upon to smash up ice twenty feet and more in thickness.

nected and fortified by bulkheads, and longitudinal bulkheads or, as we should say in landsman's language, partitions of steel framed in girders of enormous strength, that they are practically uncrushable, while the ship itself is practically unsinkable. It is divided into forty-eight water-tight compartments.

Its mission on the sea is to keep the ports of the Baltic open during the winter months by cutting a passageway for other ships through the thick ice. When it is caught, as it has been many scores of times, between a couple of closing masses of ice, it at once rises slowly and easily, and without so much as a shiver. Then, if its weight of 8000 tons is not sufficient to break the ice, its powerful pumps are set to work, and certain of its compartments are filled with water. In this way an additional weight of 2000 tons is obtained, making a total of 10,000 tons. The ice has either to support this weight or give way. Hitherto it has always done the latter. Its keel and sides are as round as an apple; there is not an angle for the ice to grip. Frequently it rescues more than 100 steamers during a season that are unable to extricate themselves from the ice.

THE MANUFACTURE OF ARMOR

THE nineteenth century gave birth to the gun's most persistent opponent, known as "armor," and the fight for supremacy between the offensive gun and the defensive armor has been going on ever since with the balance inclining first to one side, then to the other.

In so far as it is of record, John Stevens of Hoboken, New Jersey, was the first to propose the use of armor for the protection of war vessels in 1812, and now it is even used for coast defense in some cases, the forts in the harbors of Rio de Janeiro and Manila Bay containing armored turrets similar to those on ships. As is well known, the first armored war vessels in this country were the renowned *Monitor* and *Merrimac.*

Armor of all kinds and descriptions has been tried with varying success. Target structures of almost every conceivable description have been made and tested. These were plates of cast iron and wrought iron, sheets of metal bolted together and faced both flat and edgewise, alternating layers of metal and wood; of metal and rubber disposed in various ways, and of springs behind solid plates, etc. The results of all these experiments have shown that the most efficient armor is a hard-faced, tough-backed, homogeneous plate, made by what is called the "Krupp" process, after the famous German ordnance firm of that name, who were the first to make these plates.

Armor is made in this country by the Bethlehem, Carnegie, and Midvale Steel Companies, who have expended many millions of dollars in the costly and massive machinery necessary to produce these large armor plates, weighing as much as a hundred thousand pounds, and of various shapes.

The manufacture of modern face-hardened armor comprises a series of operations which requires the greatest care and attention to details to produce the best results, and these operations are so elaborate that a period of nine months is consumed in the manufacture of armor from the time the drawings showing the plates are received until the plates are completely finished and ready to be installed.

The first process in making the armor plate is the casting of the steel ingot from which the plate is to be forged. This is done in a large cast iron mold lined with sand. The molten metal from the furnace is carried in a ladle to the mold, and poured in vertical tubes connected to the bottom of the mold so that it is filled from the bottom, or "bottom poured," as it is called.

As soon as the metal has solidified and cooled off the mold is stripped from it and the ingot is picked up by a big electric crane and taken to a heating furnace to be heated for forging. Figure (1) shows one of these large ingots after it is removed from the mold by the crane; the bucket behind the two workmen is the ladle used in filling the mold. The ingot being properly heated, is removed from the furnace and forged to the approximate size of the finished plate, which is usually about one-third the thickness of the ingot. To forge a heavy armor plate requires tremendous power, and the forging presses for this purpose are very massive and powerful. Each time full pressure is applied with one of the presses it is equivalent to placing the weight of a battleship on top of the armor to mash it. The ingot is swung into position and its end placed under the upper die of the forging press, which is then

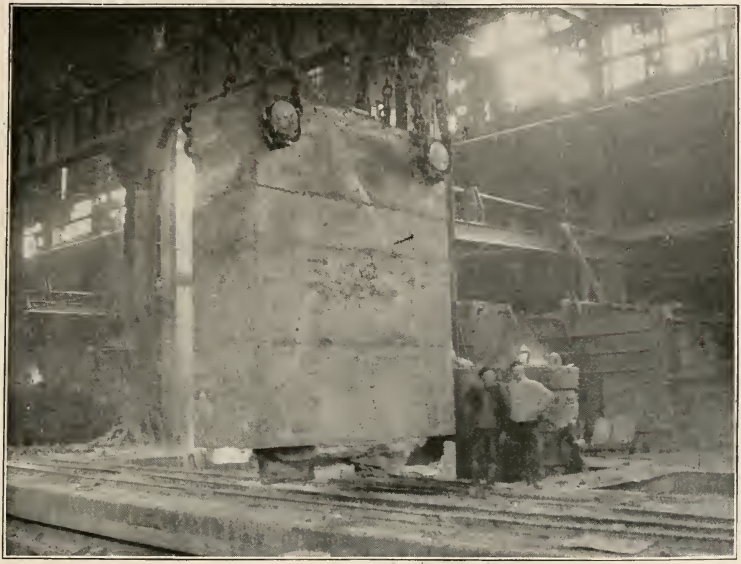


FIGURE 1. STEEL INGOT TO ARMOR PLATE

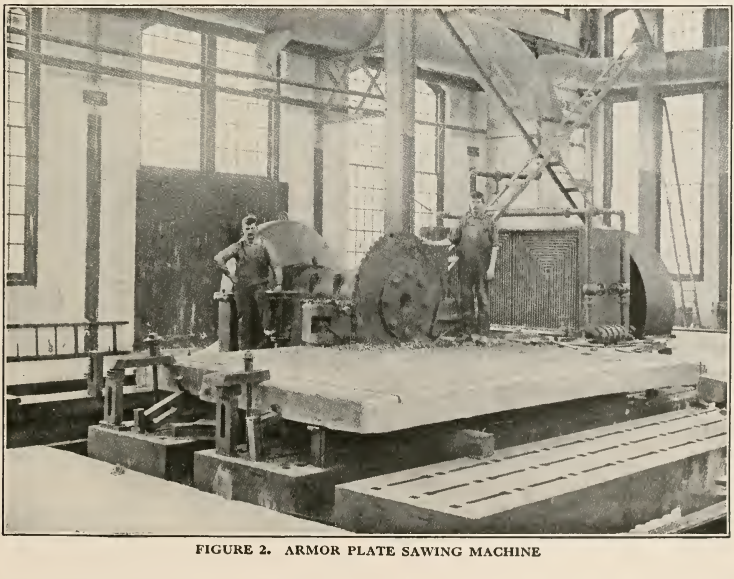


FIGURE 2. ARMOR PLATE SAWING MACHINE

FIGURE 3. BARBETTE OF BATTLESHIP "TEXAS"

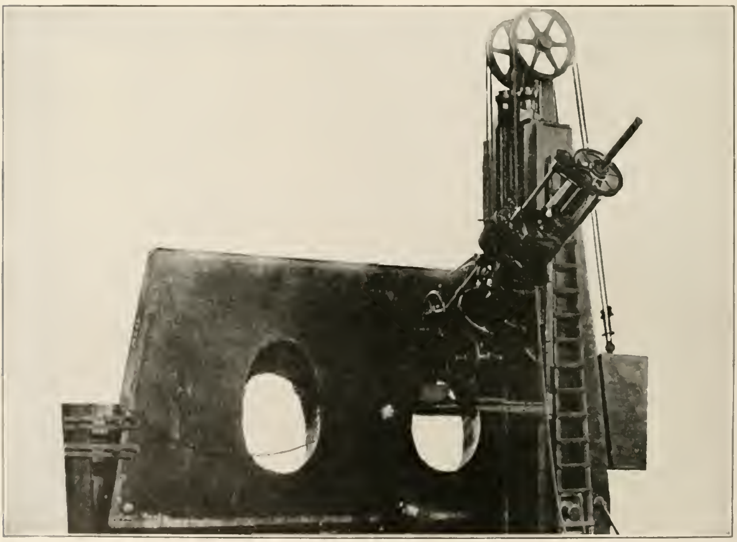


FIGURE 4. ARMOR PLATE REAMING MACHINE

forced down upon the ingot, the throw being so regulated as to diminish the thickness about 3 inches a stroke. The metal flows evenly in all directions under the irresistible and steady pressure of the press, and after each stroke the ingot is moved along until the thickness is the same throughout. Thus one sees a mass of tough steel molded into shape as if it were molasses candy.

The plate, being approximately forged, has all scale removed from its surface and is ready for "carbonizing." This is an adaptation of the well known process of cementation which means heating the metal to a high temperature in the presence of carbon, so that the carbon is absorbed by the metal. The plate is now forged to final size and then annealed to relieve any strains in the metal. It is next rough machined and then bent to shape, after which it is tempered to produce the hard face to break up the projectiles fired at it. This is done by spraying the hot face with cold water under pressure. The exact details of the above processes are manufacturers' secrets.

The plates are now ready for final machining, which is extremely difficult, owing to the toughness of the metal. The special armor plate sawing machine is shown in figure 2, cutting the edges off an armor plate. This is a very slow and laborious operation, as is all armor machining. Then the plate is put through an armor planing machine, which removes extremely small shavings at each stroke. After machining, the plates are next carefully fitted together, to insure that all joints are well made, and are an accurate and tight fit. This is called "erecting," and is done on heavy iron flooring.

Figure 3 shows the barbette of one of the turrets of the battleship *Texas*, which is eighteen inches thick and forty feet in diameter, twelve feet high, and made of seven plates keyed together. Figure 4 shows the reaming or machining of the holes for the guns in one of the turret face plates; the rough drilled hole shows on the left, and the smooth one on the right side of the picture.

After erecting the plates are disassembled and shipped on flat cars to the ships to be built in them.

Out of every lot of plates manufactured one is selected for test, and is fired at by a gun of the same size as its thickness, and it must not allow the projectile to penetrate it, otherwise the whole lot of plates is rejected. This is called the "ballistic test," and determines the quality of the armor as regards resistance to penetration. Figure 5 shows a plate that has successfully passed the ballistic test.

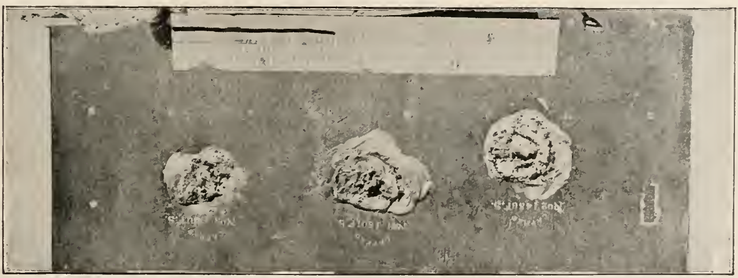


FIGURE 5. PLATE WHICH HAS SUCCESSFULLY PASSED THE BALLISTIC TEST

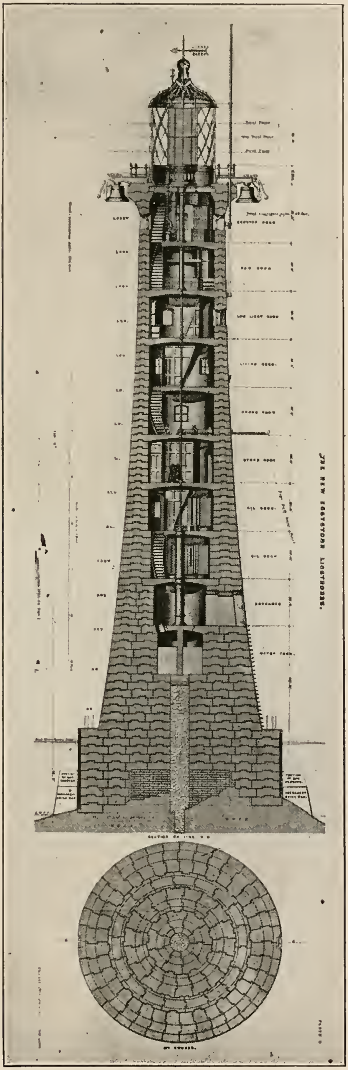
EDDYSTONE LIGHTHOUSE, ENGLISH CHANNEL

BEACONS OF THE SEA

EVER since man began to navigate the waters he has endeavored to light them at night. This he accomplishes today by the erection of beacons or towers upon the shore and rocks, from the summit of which a beam of light is automatically flashed over the ocean, and also by means of lightships and illuminated buoys. How necessary these lights are to guide and warn the mariner is obvious by the returns of wrecks.

The father of the modern lighthouse was undoubtedly the ancient Pharos of Alexandria, in Egypt, one of the seven wonders of the world. It was built by Ptolemy Philadelphus (283—247 B. C.), on a small island at the entrance to the harbor, connected by a causeway with the mainland. The Pharos cost 800 talents; if these were silver talents—as most likely they were—that would be equal to $850,000, the largest sum ever expended upon a single lighthouse. The structure had a base of some 400 feet, and towered 450 feet above sea-level. As the whole was built of white marble, the edifice must have been at once elegant and impressive. At the summit fires were kept burning to direct the mariner through the tortuous entrance of the bay. It is recorded by some of the ancients that the flame of the Pharos could be discerned 100 miles at sea. This, of course, is an exaggeration, as the most up-to-date light of modern times, with all the latest inventions for increasing its intensity, is only visible thirty miles out. It is doubtful if the smoky gleams of the ancient Pharos were

INTERIOR VIEW OF EDDYSTONE LIGHTHOUSE



This picture shows the interior structure and arrangement of one of the famous beacons of the world.

seen twenty or twenty-five miles on a clear night.

CHURCH, PALACE AND BEACON

The Romans built many lighthouses, and it is said that several exceeded in splendor and magnificence the famous Pharos, but not one of them remains. The earliest example extant of a lighthouse is the famous Tower of Cordouan, France, which dates from 805 A. D. but has been rebuilt on several occasions. The present edifice, which was begun by M. Louis de Foix, in 1584, is certainly one of the most remarkable edifices in the world. This lighthouse (originally 180, now 207 feet in height), is beacon, church, and royal residence in one, many of the French kings having occupied it.

Until the time of John Smeaton, who invented the dovetailed stone tower, lighthouses, with a few exceptions, were built of wood. It was Smeaton's success in placing a stone edifice on the dreaded Eddystone Rocks, in the eighteenth century, which gave an impetus to lighthouse building.

Smeaton's first tower of solid stone braved the elements on the Eddystone for 123 years, when it was dismantled and reerected on the Hoe at Plymouth, and another tower put up in its place on an adjoining reef. The reason for the removal of the lighthouse was that the rock on which it stood had been worn away by the action of the sea. Long before this occurred, however, it had been demonstrated that the stone tower was the best device for equipping a wave-washed rock with a light. Stone towers sprang into existence on dreary rocks around the British Isles and in America.

There are now about 260 lighthouses around the coasts of Great Britain alone, and 762, having resident keepers, within the jurisdiction of the United States.

THE PRESENT BOSTON LIGHT
Built in 1783 by Massachusetts and ceded to the United States in 1790

First American Lighthouse

The first lighthouse on the American continent was built by the province of Massachusetts, 1715-16, on an island at the entrance to Boston harbor. The light was supported by light dues of one penny per ton, levied by the receiver of impost at Boston on all incoming and outgoing vessels except coasters. This lighthouse was an object of attack during the early part of the Revolutionary War, and was burned by the Americans and finally blown up by the British in 1776. A new lighthouse on the same site was built in 1783 by Massachusetts, and this, with various alterations, is the present Boston light.

Although candles and even coal fires have been used in lighthouse illumination in England to a much later date, Boston light was probably illuminated from the first by oil lamps. In 1789 the light was produced by 16 lamps in groups of 4. Crude lenses and reflectors were fitted in 1811, and also revolving mechanism, it having previously been a fixed light. In 1838 Boston light is described as "a revolving light, consisting of 14 Argand lamps, with parabolic reflectors," the lamps being "of about the volume of similar lamps in family use." In 1839 large reflectors 21 inches in diameter were fitted to this light. Boston light was provided with a Fresnel lens in 1859.

Apparently a great gun was the only fog signal at this station until about 1852, when a fog-bell was installed. A mechanical striking bell was installed in 1869, in 1872 a fog trumpet, and in 1887 an air siren.

The oldest of the existing lighthouse structures in this country is the tower at Sandy Hook, New York, built in 1764. The lighthouse at Cape Henlopen, Delaware, was completed the same year. These are similar in design—massive structures of stone and brick, with walls 7 feet thick at the base.

SANDY HOOK LIGHTHOUSE, NEW YORK

This and Cape Henlopen lighthouse, both built in 1764, are the oldest existing lighthouse towers in this country. The walls at the base are 7 feet thick.

LOCATION AND CONSTRUCTION OF LIGHTHOUSES

The first-class light and fog-signal stations are located at the more prominent and dangerous points along the seaboard, and on a well-lighted coast such stations should be sufficiently close that a coasting vessel may always be in sight of a light. The smaller lights are placed to mark harbors, inside channels, and dangers. Along the navigable rivers numerous post lights are maintained to indicate the channels.

For New York harbor and immediate approaches alone 268 aids to navigation are required, including 46 shore lights, two light vessels, and 36 lighted buoys; there are 192 buoys of all classes and 37 fog signals, including sounding buoys.

At the principal stations provision is made either in the tower or in separate buildings for the mechanical equipment connected with light and fog signal, for storage of oil and supplies, for quarters for keepers and their families, boats, etc.

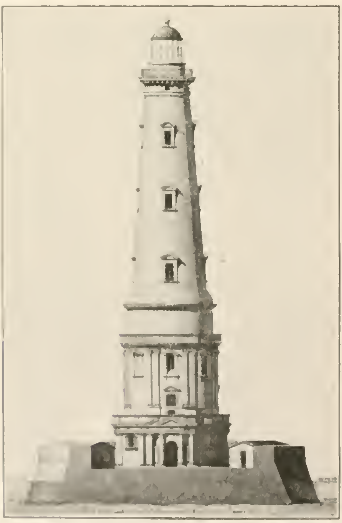
Various materials have been employed in lighthouse construction—stone, brick, iron, steel, concrete, reinforced concrete, and wood; in new work, however, the latter is now little used because of the desirability of permanency.

WONDERFUL SEA-SWEPT LIGHTHOUSES

Lighthouse construction on the land is usually comparatively simple, except when there is difficulty of access to the site. But often it is important for the protection of shipping that lighthouses be erected either on rocks or reefs exposed to the sea or actually in the water, on sand or rock bottom. Such work has called forth the greatest skill of engineers.

Numerous types of construction have been used. Where the foundation is exposed, even at the lowest tides, masonry towers have been, with great labor and often danger, fitted to the bed-rock; otherwise the structure has been erected on iron piles driven, screwed, or pumped into the sand or coral, or on caissons floated to the site and set on the bottom or sunk deeper by the pneumatic process, or by the use of coffer-dams, within which the masonry tower has been erected; smaller structures have been placed on rip-rap foundations.

The earliest example now existing of a sea-swept lighthouse is the beautiful tower of Cordouan, built in 1584 to 1611, on a rock in the sea at the mouth of the Gironde, on the west coast of France. This lighthouse



The beautiful lighthouse on the coast of France, Phare de Cordouan, completed in 1611 and since altered: the oldest sea-swept lighthouse now in existence.

has since been altered and raised in height. The original structure was elaborately decorated, and one floor was occupied by a chapel.

The most famous of the sea-swept lighthouses is the Eddystone, 13 miles from Plymouth harbor, England. This was completed in 1699, after four years of work. During the first year all that was accomplished was drilling 12 holes in the rock and fastening irons in them. This lighthouse, with the keepers and the engineer who built it, disappeared in the great storm of November, 1703, and since that time three other lighthouses have in succession been erected on the Eddystone.

MINOTS LEDGE LIGHT

The earliest lighthouse built in this country in a dangerous position, exposed to the open ocean, was that on Minots Ledge, a reef off Boston harbor which had long been a terror to mariners.

There was a great gale in April, 1851. "The light on the Minot was last seen from Cohasset on Wednesday night at 10 o'clock. At 1 o'clock Thursday morning, the 17th, the lighthouse bell was heard on shore, one and one-half miles distant; and this being the hour of high water, or rather the turn of the tide, when from the opposition of the wind and the tide it is supposed that the sea was at its very highest mark; and it was at that hour, it is generally believed, that the lighthouse was destroyed; at daylight nothing of it was visible from shore, and hence it is most probable it was overthrown at or about the hour named." Two keepers were in the tower and were lost, and this extract from the official report tells the story of one of the great lighthouse tragedies.

The present massive stone lighthouse was built on the same site on Minots Ledge, commenced in 1855 and completed in 1860. It ranks among the difficult lighthouse engineering works of the world. During the first summer only 130 working hours were obtained on the rock, and after three years' work only four stones of the foundation were laid. The reef rock was prepared to fit the stones of the lower courses and the latter were cut to interlock. Dwellings for the keepers' families were built on the shore, accommodations for the men only being provided in the tower.

Longfellow visited Minots light in 1871, and in a letter thus describes it: "The lighthouse rises out of the sea like a beautiful stone cannon, mouth upward, belching forth only friendly fires."

White shoal light

White Shoal, a dangerous spot in Lake Michigan, at the entrance to the Straits of Mackinac, was marked for 19 years by a light vessel anchored over it. On account of the ice, this vessel could not be kept on the station during a portion of the season of navigation in the spring and fall. As the unmarked shoal was a serious menace to navigation at these seasons, an appropriation was made for building a lighthouse, and this was completed in 1911 at a cost of $225,000.

A timber crib 72 feet square and 18 feet high was built on shore and floated out to the site, where the depth of water was 22 feet. The bottom, which is of coarse gravel, was covered with 2 feet of rock, and the crib was filled with stone and sunk. Above this was built a concrete pier, which supports the lighthouse.

The light is of 1,200,000 candle power, flashing white every 8 seconds. In addition to the compressed air fog-whistle there is a submarine bell signal, located in 60 feet of water three-quarters of a mile from the station. This bell is supported on a tripod standing on the bottom of the lake, is operated by electric power transmitted through a cable from the light station, and strikes "23."

Tillamook rock—one of the most exposed in the world

Two lighthouses involving great difficulties have been built on rocky islets of the Pacific coast—Tillamook Rock, completed in 1881, and St. George Reef in 1891. Tillamook is a high, precipitous rock south of the Columbia River and about a mile from shore. It is exposed to the sweep of the Pacific Ocean. Landing on the rock was very dangerous, and the foreman was drowned the first day a working party was landed. There was serious difficulty in providing any protection on the rock for the workmen. It was necessary to blast off the top of the rock to secure sufficient room for the lighthouse.

THE TILLAMOOK ROCK LIGHT COMPLETED
The seas here are terrific. On October 19, 1912, a wave broke a pane of the lantern 132 feet above the sea.

This light station is one of the most exposed in the world. The tower is 136 feet above high water, but the keepers reported that in a storm in 1887 the seas broke over the building, some going above the tower, and serious damage was done. In another storm a mass of concrete "filling weighing half a ton was thrown over the fence into the enclosure," at a level of 88 feet above the sea.

St. George Reef Light, California

St. George Reef light is built on a rock lying 6 miles off the northern coast of California. The rock was so exposed and swept by the seas that workmen could not safely live upon it, and it was necessary to moor a schooner near the rock to provide quarters for the men, who were transported back and forth by a traveler on a cable. The total cost of the work at St. George Reef was about $712,000, making it the most expensive lighthouse that has been built in this country. These two exposed light stations on the Pacific coast are the only ones having five keepers.

Famous Shore Lights

The tallest light-tower in the United States is that at Cape Hatteras, on the low-lying coast of North Carolina, which is 200 feet from base to top of lantern. The highest light, however, is that at Cape Mendocino, on the coast of California, which is shown 422 feet above high water; it is on a cliff, the lighthouse itself being only 20 feet in height.

Troubles from Ice, Birds, and Sand

Sand creates difficulties at some light stations located among dunes or shifting wastes of sand. At Cape Henlopen the sand driven by the wind has cut deeply into the wood framing of the keepers' dwellings, and has ground the window glass so that it is no longer transparent; but the lantern of the light is too high to be so affected.

Even the flying birds make trouble at lighthouses, as the brilliant light so attracts them that they will fly directly for it, and striking the heavy glass of the lantern are killed.

From Wood Fires and Candles to Oil Vapor and Electric Lamps

The early lighthouses were lighted by wood or coal fires burned in open braziers, and later by candles inclosed

THE TALLEST LIGHT TOWER OF THIS COUNTRY, 200 FEET HIGH; THE CAPE HATTERAS LIGHTHOUSE, NORTH CAROLINA

The spiral painting is to furnish a distinctive day-mark to mariners. "A light must be about 200 feet above the water to be seen from the deck of a vessel 20 nautical miles distant; beyond that distance the curvature of the earth would prevent a light at this elevation being seen."

in lanterns; the resulting light was necessarily weak and fitful, and a large part was lost by being diffused in directions of no use to mariners. Oil lamps were early introduced in this country and at the present time lamps with from one to five concentric wicks, and burning a high grade of kerosene oil, are used in a majority of lighthouses. For the more important lights the incandescent oil vapor lamp is now used. In this lamp the oil is heated and then vaporized, and is burned mixed with air under a mantle which is made incandescent.

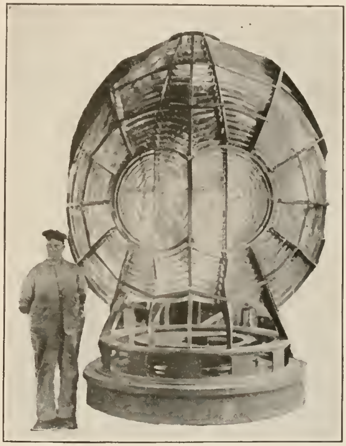
Electric lights are used at a few light stations only. The expense is too great to warrant the employment of electricity at many important stations.

The electric light at Navesink, on the highlands just south of New York harbor, is the most powerful coast light in the United States. This light shows each five seconds a flash of one-tenth second duration estimated at 60 million candle power. Although, on account of the curvature of the earth, the light itself cannot be seen more than 22 miles, its beam has been reported to have been observed in the sky at a distance of 70 nautical miles.

Powerful Reflectors, Lenses, and Prisms Are Used

In order to increase the effectiveness of illumination, reflectors, lenses, and prisms are used to concentrate the light and throw it out either in a plane around the horizon or in a beam or limited arc, where it will be most useful.

With the most complete lenses about 60 per cent of the light is rendered useful, the balance being lost at the top and bottom and by absorption of the glass of the lens and the lantern. The largest lens in service is that at Makapuu Point light, Hawaii, which is 8¾ feet in diameter.



A BEAUTIFUL GLASS LENS AND MOUNTING RECENTLY BUILT IN FRANCE FOR THE KILAUEA LIGHTHOUSE NOW UNDER CONSTRUCTION IN THE HAWAIIAN ISLANDS

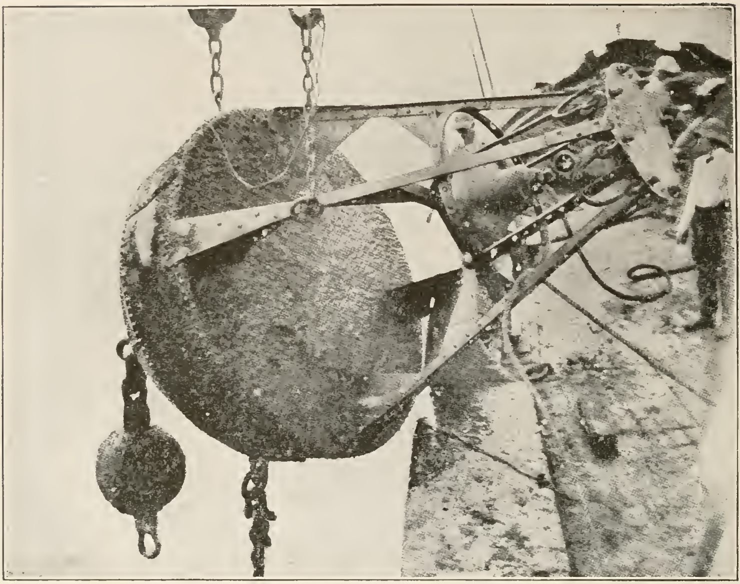
It will be the landfall light approaching the islands from Japan. The light will give a double flash of 940,000 candle power every 10 seconds. The lens and mounting "weighs nearly 4 tons and turns on a mercury float, making a complete revolution every 20 seconds and giving a double flash of about 940,000 candle power every 10 seconds. The light is sufficiently powerful to be visible 40 miles, but because of the earth's curvature it can be seen only 21 miles."

The most powerful flashing lights are arranged to have the entire lens revolve, the beam from each panel of the lens appearing as a flash as it sweeps past the observer. To obtain rapid and smooth revolution, the lens is mounted on a mercury float, and a lens weighing, with fittings, as much as 7 tons may make a complete revolution in 30 seconds.

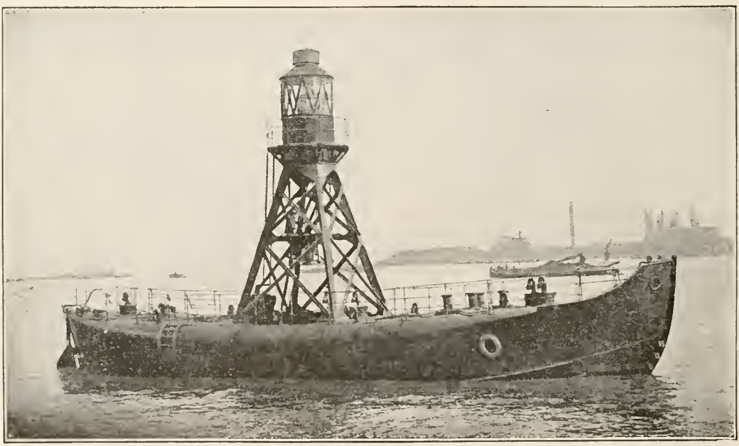
A recent example is the lens for Kilauea light station, Hawaiian Islands.

Buoys

Floating buoys are efficient and relatively inexpensive aids to navigation. They are used to mark dangers—as shoals, rocks, or wrecks—to indicate the limits of navigable channels, or to show the approach to a channel. They vary in character



A BELL BUOY TAKEN ON BOARD LIGHTHOUSE TENDER
Shows marine growth and the necessity for periodic cleaning and painting of buoys



AN UNATTENDED LIGHT VESSEL ON THE COAST OF ENGLAND
It has no crew, and is equipped with flashing gas light, aerial fog bell, and submarine fog bell, all automatic. The bells are operated by the motion of the vessel in the sea.

according to their purpose or the distance at which they should be seen. The simpler forms are the wooden and iron spar buoys, and iron can and nun buoys. For warning in thick weather, buoys are fitted with bells, whistles, and submarine bells, all actuated by the motion of the sea.

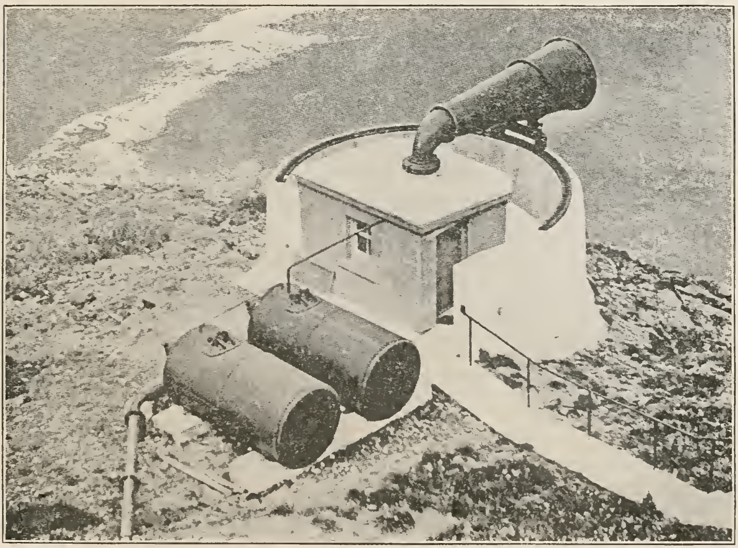
Some important buoys are lighted, usually by means of oil gas compressed in the buoy itself or acetylene gas compressed in tanks placed in the buoy or generated in it.

The buoy off the entrance to Ambrose Channel, New York harbor, at a height of 27 feet above the water, shows a light of 810 candle power, occulting every 10 seconds and visible 10 miles. This buoy recently burned for one year and four months without recharging. The buoy is nearly 60 feet long and weighs over 17 tons.

FOG SIGNALS

The most powerful coast lights may be rendered of little or no use to navigation by thick fog or rain. To assist vessels under such conditions, making their course more safe or allowing them to proceed, fog signals of many sorts have been established. Of these the bell is the most common.

The fog signals now in use in the United States, consist of sirens, whistles, reed trumpets, aerial bells, and submarine bells. Sirens and whistles are operated by compressed air or steam, and trumpets by compressed air. To furnish air, compressors driven by internal combustion engines are used, and for steam signals boilers are employed. The larger fog bells, up to 4000 pounds, have hammers actuated by a weight and clockwork. The smaller bells are rung by hand.



There is nothing sailors dread more than a fog, when lighthouses and lightships become useless. The sailors are like men deprived of their sight. Then it is that the foghorns begin to sound. A foghorn is often heard for twenty miles, but in some weathers only for one or two miles. This picture shows the Bass Rock foghorn.

THE RACINE REEF LIGHTHOUSE, IN LAKE MICHIGAN, COVERED WITH ICE

Winter seriously increases the work of maintaining aids to navigation; the spray or sleet freezing may completely envelop the tower in ice, obscuring the light until the lantern is cleared. In northern waters, where there is floating ice, many of the gas buoys must be removed in winter and replaced by spar buoys, over which the ice may pass without serious damage to the buoy. The spray freezes to bell buoys sometimes until the weight of ice overturns them.

Besides the above, there are various noise-making buoys; bells, whistles, and submarine bells are attached to buoys and are made to sound by the movement of the buoy due to the sea. Nearly all fog signals excepting those on buoys are operated to sound a characteristic signal so that they may be distinguished, there being a succession of blasts or groups of blasts or strokes at regular time intervals, which are made known for each station. Even adjacent buoys are differentiated by the use of whistles and bells and by variation of tone.

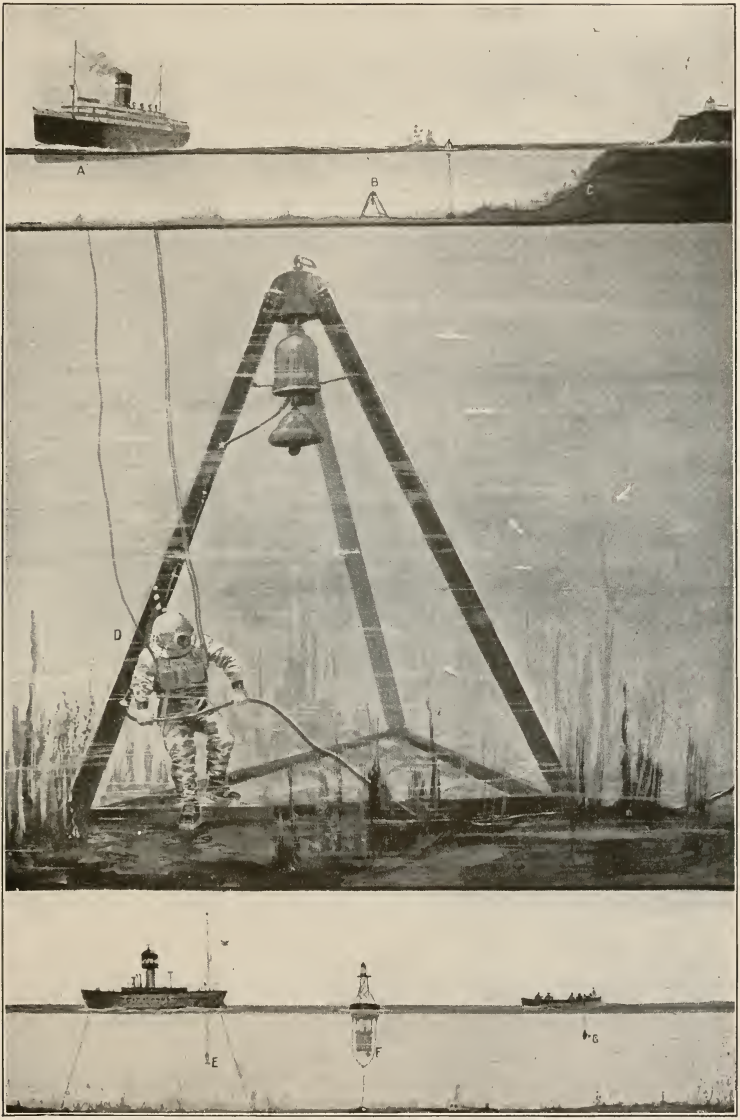
SUBMARINE BELLS

Submarine bells were first regularly employed as fog signals in the United States in 1906. The bell is suspended in the water from a light vessel to a depth of 25 to 30 feet and is operated by compressed air, or the bell is mounted on a tripod on the bottom and worked by electric power transmitted from the shore through a cable, or it is suspended from a buoy and actuated by the motion of the sea, which moves a vane and winds a spring. Submarine bells have frequently been heard through the water at distances of 15 miles and more.

AN UNATTENDED FLASHING GAS LIGHT ON RICHARDSON'S ROCK, CALIFORNIA

This light will flash every three seconds for seven months before it requires another charge of gas. This would be a difficult and expensive site on which to establish a regular lighthouse with keeper's quarters.

HOW LIFE SAVING BELLS ARE FIXED AND WORKED



A. Position of receiving apparatus in bow of ship. B. Tripod and bell attached to a lighthouse. C. Electric cable. D. Diver laying a submarine bell. E. Submarine bell suspended from a lightship. F. Submarine bell buoy. G. Handworked boat gong.

THE WORLD'S GREATEST WATERFALLS AND GREATEST SOURCE OF POWER

BIRDSEYE VIEW OF NIAGARA FALLS SHOWING POWER DEVELOPMENT ON CANADIAN SIDE

HARNESSING THE WORLD'S GREAT WATERFALLS

THE POWER OF A DROP OF WATER

PROBABLY nothing in the universe is regarded by the majority of people as of less importance than a drop of water. If we want to say how insignificant a thing is, and how little work it can accomplish, we usually say it is like "a drop in the ocean." And yet the power in a drop of water is so vast that, added to the power in every other drop, it could do all the work of the world a thousand times over. This is no new discovery, for it has been known from very early times. Solomon had discovered the power of water when he wrote, "A continual dropping weareth away stone." But it is only now, in these days in which we live, that men are making practical use of the tremendous fact that water has stored up in it energy enough to light our cities, drive our machinery, and move our trains—energy so tremendous that the power of coal and steam are weak and old-fashioned compared with it.

It has been stated by a great engineer that within a very few years, in all those countries that have waterfalls and swiftly flowing rivers, trains will no longer be driven by steam, and streets be lighted by gas, but electricity will be used for everything, not only because it is so much better, but because it will be cheaper than any other kind of power. And this mighty step forward will all be due to the power that lies in a drop of water.

If we put our finger under the water-faucet and then turn on the water, we find that the water presses with such force against the finger that it cannot be held in, but spurts out all around. What, then, must be the accumulated force of a mighty mass of water falling from a great height.

The world over men are now harnessing the force of falling water, which for thousands of years has been running to waste. The most notable example of this is that of Niagara.

Long ago, engineers realized that if only a fraction of the water could be harnessed, Niagara Falls could be made to do a vast amount of work. It has been estimated by some expert that the power running to waste at the falls is equal to five million horsepower, more than double that of all the coal mined in the state of Pennsylvania, if that were used in furnaces and turned into steam. This power is worth tens of millions of dollars a year, and yet, until recently, all that it has done has been to wear away a deep bed for the river in the solid rock.

Period of Discovery

The Niagara Falls were only discovered by white men in 1678, and it has been said that up to that time the roaring waters had been feared. Then they were admired, and now, at last, they are being used to develop the greatest electrical power plant in the world. This development is the pioneer and leader of the electrical age.

The Niagara River falls 300 feet in five miles, 50 feet in the upper rapids, 165 feet at the falls and 85 feet in the lower river. In its entire length of 36 miles, the river falls 326 feet. The total power-producing capacity of the great cataracts is estimated at from five million to seven million horsepower, and five companies are now developing about 450,000 horsepower on both the American and Canadian sides of the river. The average flow of the river is 122,400 cubic feet per second. A flow of one cubic foot per second equals one square mile of water 1.16 inches deep in a 30-day month. The flow of the Niagara River is furnished by six thousand cubic miles or from four lakes having 90,000 square miles of reservoir space. The extreme width of the river is one mile, and the two channels above the falls are 3800 feet wide. The American fall is 165 feet high and one thousand feet wide, and the Horseshoe falls is 159 feet high and 2600 feet in width. The greatest depth of the river just below the falls is 192 feet. The power of the Niagara Rapids and falls is estimated to equal the power available or being generated from all the coal mined daily—about 200,000 tons. The flow of water over the Falls of Niagara is about 25 million tons an hour or one cubic mile per week.

Beginning of power development

The beginning of the project of the electrical development of power at Niagara Falls was the passage by the New York Legislature of a special charter in 1886, granting to the Niagara Falls Power Company the right to develop 120,000 horsepower for a tunnel. The projectors estimated that 120,000 horsepower exceeds the theoretical power at Lawrence, Holyoke, Lowell, Turners Falls, Manchester, Windsor Locks, Bellows Falls, and Cohoes, and exceeds the power actually developed at these places and at Augusta, Paterson and Minneapolis. The company was then given the right to construct a tunnel with a capacity of 100,000 horsepower more.

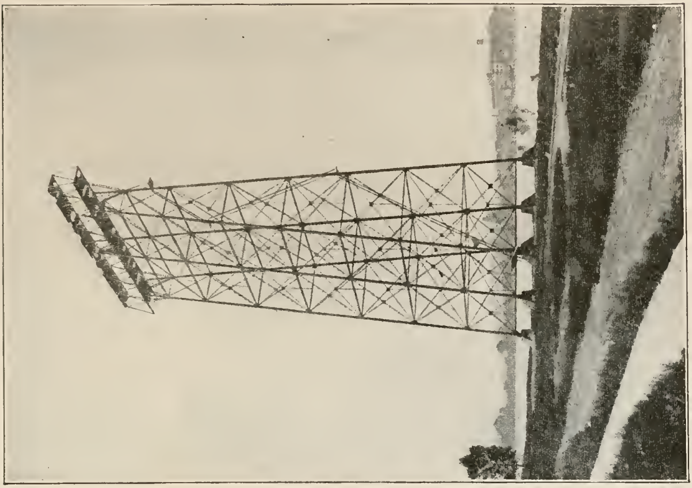
The work of excavation for the tunnel was started October, 1890. The intake canal, one and one-quarter miles above the falls, is 250 feet wide, twelve feet deep and 1200 feet long. The wheelpit is 178 feet deep. The tunnel is 7481 feet long and the interior dimensions 21 feet by 185 feet six inches. It runs about 200 feet below the City of Niagara Falls. The velocity of the water flowing through it is about 20 miles an hour, the slope being six feet in one thousand feet. In excavating for it 300,000 tons of rock were taken out. For lining it 16 million bricks were used. The initial installation was for 15,000 horsepower. This company and its auxiliary, the Canadian Niagara Power Company, are now developing about 160,000 horsepower and diverting less than four percent of the flow of the river. Its generators are of 5000 and 5500 horsepower in its two power houses at Niagara Falls, New York, and of 10,000 horsepower at its plant at Niagara Falls, Ontario.

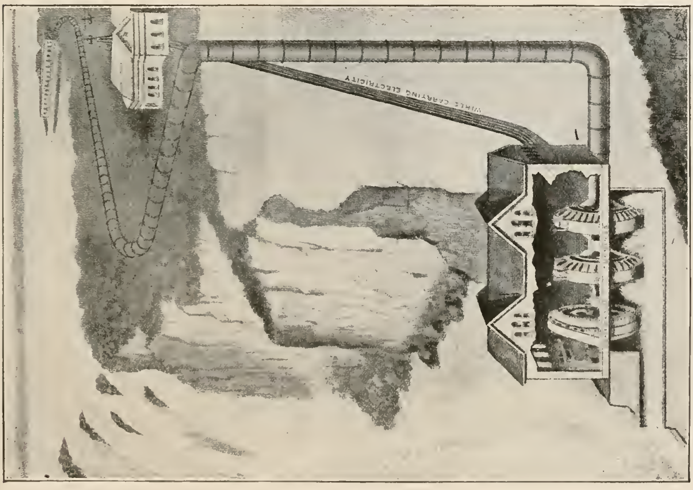
Output of five power stations

Today electrical energy equal to 580,000 horsepower is obtained from this single waterfall. This is the combined output of the five power stations that dot the banks of the Niagara River. Two are on American territory and three on Canadian soil. The latter are far and away the largest institutions of their kind in existence. generating 110,000, 125,000, and 180,000 horsepower respectively.

Here it may be mentioned that one horsepower represents the hard labor of at least ten men, so that the Niagara development of today seems, at first glance, to represent the energy of 5,800,000 men. But man has elected to work no more than eight hours a day, while Niagara gives out its power from sunrise to sunrise, so that the Niagara development stands for the force of 17,400,000 able-bodied men.

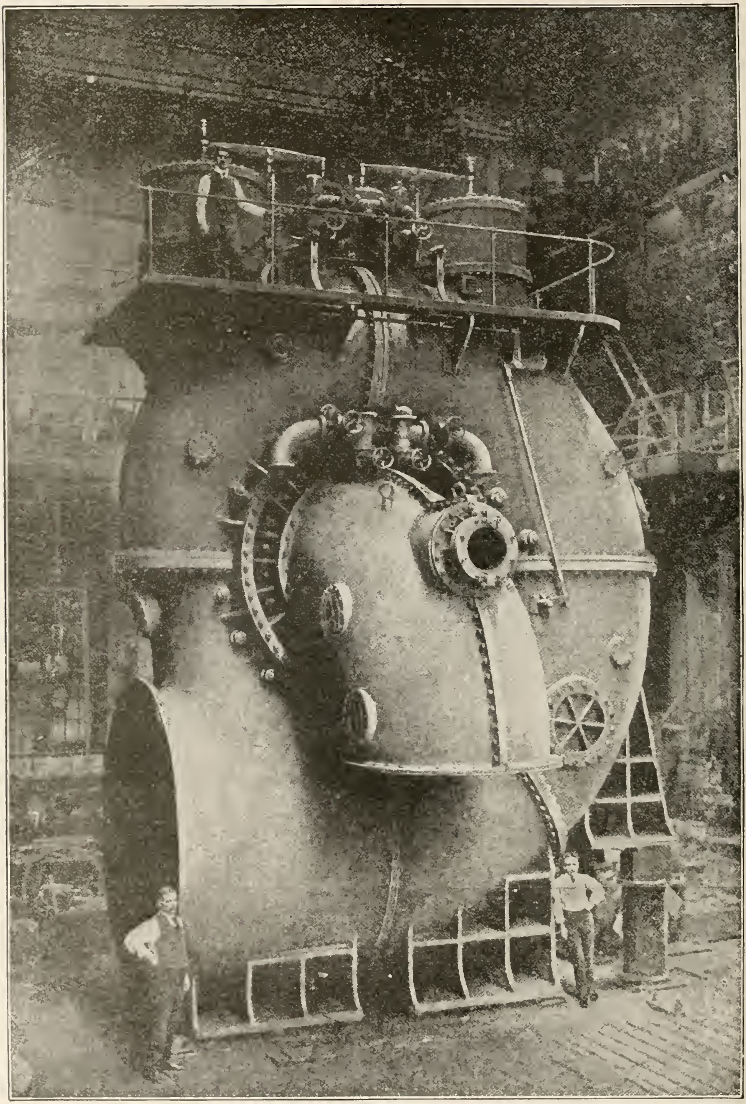
WE CAN SEE AT A GLANCE IN THIS PICTURE HOW THE NIAGARA FALLS ARE HARNESSED





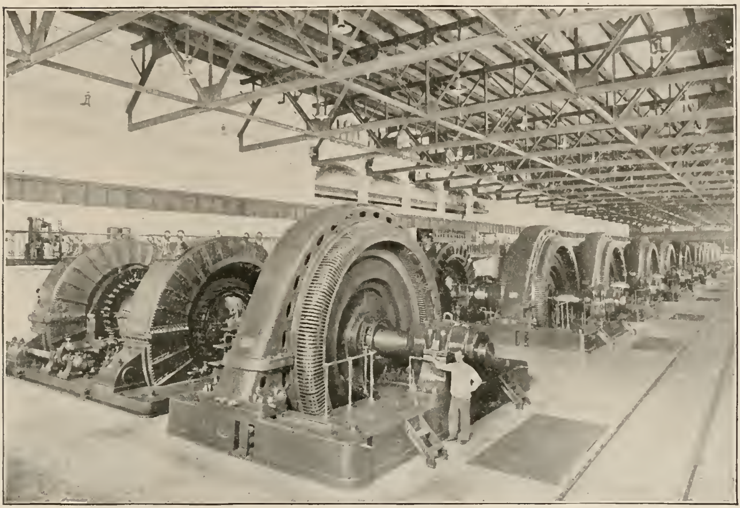
A great wall is built out into the river to divert part of the water to what is called the forebay. From here the water passes into the penstock, the huge pipe through which it falls 180 feet with terrific force, turning the turbines at the bottom. The turbines, in their turn, revolve the generator, which generates the electricity. The current is carried by wires to the distributing station. The wires which distribute the electricity generated by the turbines are carried to the cities and towns on high steel towers to light cities, drive cars, and work the machinery of great factories over an area of hundreds of square miles. The tower shown in this picture is over two hundred feet high. The wires to Toronto, 88 miles away, run over a private road 80 feet wide.

THE GIGANTIC WHEEL TURNED BY NIAGARA

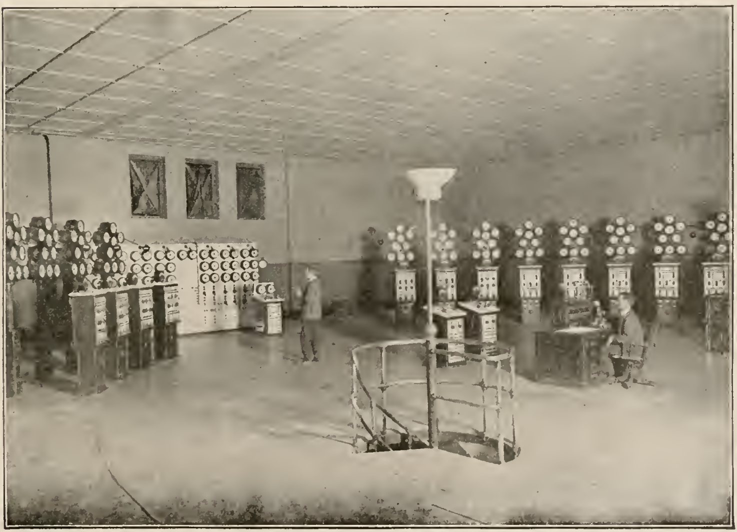


This picture, showing the outside of a turbine, gives some idea of the tremendous size of these marvelous steel waterwheels. The wheel that revolves inside this will generate enough electricity to light a town, and the entire turbine weighs 180 tons.

HOW POWER IS GENERATED AND CONTROLLED



INTERIOR OF GENERATING STATION, ONTARIO POWER COMPANY



CONTROL ROOM, ONTARIO POWER COMPANY

Putting Niagara to work in this fashion has resulted in a great manufacturing city arising on the American side of the falls, in which not a single steam-engine pants, though coal is very cheap in the locality. Even in Buffalo, where coal costs only a nominal sum, electric power, transmitted 23 miles from the falls, has completely ousted steam—a fact which is not a matter of astonishment, considering that the generating companies supply current at the rate of $25 per year per horsepower, running continuously. Every year the great electrical tentacles reach out farther and farther, and grip town after town. Already the street cars of Syracuse on the east and Toronto on the west—250 miles apart—are operated by Niagara power, as is also a section of the Erie Railway, 150 miles distant. Within a short time from now towns 300 miles away and more will be tapping the energy of the famous falls.

No visible wheels which indicate power

There are stories told of tourists visiting the falls who, after being impressed by their grandeur, ask, "Where are the wheels from which the power is obtained?" As a matter of fact, there is nothing at all at the falls themselves to indicate that man has in any way harnessed them for his benefit. But at five points on the river, above the falls, there are little dams or openings into which the water runs, and, by falling upon turbines laid deep down in the bowels of the earth, generates the power. These turbines are in all cases situated from 170 to 180 feet below the surface of the river, and the water is supplied through vertical pipes, known as penstocks.

A turbine is composed of a number of vanes set spoke-wise round an axis, and enclosed in a cylinder in such a fashion that all water passing through the cylinder must push the vanes aside in its course, imparting to them, and therefore to their axis, a circular motion. Attached to the turbines are revolving shafts of steel reaching up to the generators in the power house on the surface of the ground, which operate the dynamos and thus produce the electrical energy.

In the case of the new Canadian power houses, the tunnels or penstocks are of immense size, and were laboriously cut through the solid rock. The largest is 11 feet in diameter. At their bases there are deep wheel-pits in which the various turbines do their mighty work. To get rid of the water after it has passed through the turbines, channels have been bored through the rock on a gentle gradient to points below the falls.

Driving a tail-race

The tunnel, or "tail-race," of the Niagara Falls Power Company, the first to be erected, is 7000 feet long, with a maximum section of 21 feet by 18 feet 10 inches. The driving of this tunnel occupied 1000 men continuously for three years, required the removal of 300,000 tons of rock, and consumed 16,000,000 bricks for its lining. Add the quarrying out of 123,455 cubic yards of rock for the wheel-pits, and it will be realized that here a very considerable engineering feat has been performed.

Of the Canadian power-stations the largest is that belonging to the Ontario Power Company, the output of which is 180,000 horsepower. Its erection was a bold and daring undertaking. About a mile above the falls a great wall 600 feet long was built out obliquely into the river, slanting downstream. From here water passes into the tunnel and down on to the turbines in the giant wheel-pit, an ingenious arrangement of sluice-gates and gratings keeping back any ice that is brought down by the river during the winter months. The tunnel or penstock is 7 feet by 15 feet, and from its base a lateral tunnel, 8 feet by 15 feet, has been driven out, 400 feet back of the Horseshoe Fall, to carry off the "dead" water.

The piercing of the rocky cliff in the rear of the Horseshoe Fall by this lateral tunnel was one of the most notable engineering exploits Niagara has known in connection with its magnificent power development.

So far as the power-houses are concerned, all that the visitor detects are rows of mighty dynamos, the largest in the world, while he is conscious of a ceaseless hum. This is caused by the armatures as they spin round at a speed of 1500 revolutions per minute. The outcome of this activity is that power is generated, and, by means of specially designed cables, carried to distant places to be used as desired.

In the same way man has harnessed the famous Victoria Falls, on the Zambesi, in South Africa. These falls have a drop of close upon 400 feet and are more than a mile in width. Their potential energy is estimated to be fully 35,000,000 horsepower, several times as great as that of Niagara. Here it is interesting to note that if the whole of the waterfalls of Europe, both large and small, were utilized in the service of man tomorrow, they would not aggregate more horsepower than that which could be obtained from this single waterfall in South Africa. So far man has only tapped a fraction of this enormous energy now running to waste at the "Roaring of the Waters," namely, some 150,000 horsepower, less than one two-hundredth part of the whole.

As Niagara and the Victoria Falls have been harnessed so, no doubt, in course of time, the same fate will overtake the Yguazu Falls situated on the river of that name, a tributary of the Parana, in South America. These falls are over two miles wide and have a drop of 215 feet. Here is continually running to waste some 14,000,000 horsepower.

FAMOUS EUROPEAN WATERFALLS

The great waterfalls of Europe have long been harnessed to the service of man. The Rhine Falls at Schaffhausen, the most voluminous of European waterfalls, now generate electricity for a variety of purposes. Then the Rjukan Falls of the Maan-Elf River, in the Norwegian province of Telemarken, have been tamed recently, a 125,000 horsepower plant having been erected there. This is the highest waterfall in Europe. The principal fall is 800 feet high, and the total height of the two chief falls with the intervening rapids amounts to 1837 feet, while the average flow of water is 1760 cubic feet per second. The Falls of Trollhattan, the most celebrated of all Scandinavian waterfalls, now work for man, generating something like 40,000 horsepower. Indeed, the total energy man obtains today from falling water, in Europe alone, represents, it is estimated, not less than 8,650,000 horsepower. Yet we are but on the verge of a revolution in our methods of obtaining energy for locomotion, lighting, heating, and factory operations, for there are many falls and large volumes of water still running free that are capable of being tamed for man's service.

Electric current is sold by the horsepower and also by measure and watt hour. The volt is the unit of electrical current. A volt multiplied by an ampere is a watt. A watt is the unit of electrical power. One thousand watts make a kilowatt. Seven hundred and forty-six watts make one horsepower.

THE KEOKUK DAM ACROSS THE FATHER OF WATERS

FOR more than half a century dwellers upon either shore of the Mississippi near the Des Moines rapids have watched the rushing waters and longed for the day when the mighty river should be harnessed for the benefit of mankind. For many years such an undertaking was impossible. But the advent of the "concrete age" has enlarged the powers of the engineer and the wonderful development of the Middle West has at last furnished the capital essential to the stupendous undertaking.

This greatest of all water-power developments is the outgrowth of public energy exerted continuously over a long series of years, although the last ten years only were the ones productive of tangible results. The work was started by the organization of a small corporation, consisting really of the people of Keokuk, Iowa, and Hamilton, Ill., organized to facilitate action, the money necessary to launch the enterprise being paid from the respective city treasuries.

SAFEGUARDING THE RIGHTS OF THE PUBLIC

Upon petition Congress accorded to this corporation the rights and franchises essential to the construction of a dam at Keokuk. But the act granting the franchise placed every detail of the work under the supervision of the War Department. It was also provided that a colossal lock of the Panama type should be constructed and an immense dry dock, and that these should become the property of the Federal Government and yet be perpetually operated at the expense of the corporation.

The Government also secured deep-water navigation for sixty-five miles above the proposed dam.

SEARCHING FOR CAPITAL TO BUILD THE DAM

The local corporation, after receiving its franchise from Congress, began a search for some one to take over its rights and construct the dam. It finally came in contact with Hugh L. Cooper, who had built many large water plants, including the great one at Niagara Falls. He became much interested in the Keokuk project and a few years later he built the great dam and as its chief engineer attained international fame.

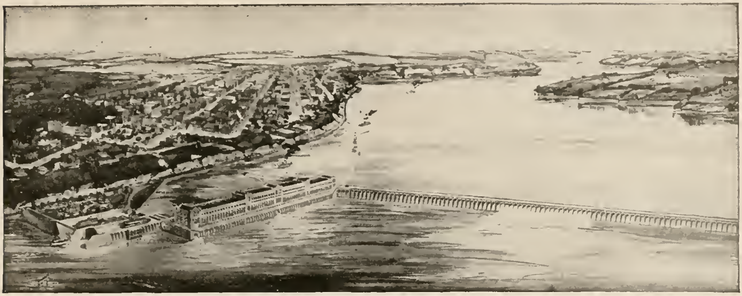
But the intervening years were nerve-racking ones. The first fifty-eight capitalists Mr. Cooper approached turned him away coldly, saying the proposition could not be made a success. He spent all his own assets in the search for capital. Just before the five years provided in the franchise for beginning work expired, Stone & Webster, a Boston financial house, heavily interested in public utilities throughout the country, agreed to finance the proposition and gather the capital for it, which they did, largely in Europe.

A year was spent partly in construction, but chiefly in assembling an organization of hundreds of engineers, thousands of workmen and over a million dollars' worth of machinery, most of it built from original designs for the work. Then the entire dam was rushed to completion in about two years, although it contains the same amount of masonry as the great pyramid of Cheops which is said to have required for its building the labor of a hundred thousand men for about a hundred years.

THE LARGEST POWER DAM IN THE WORLD

The Keokuk dam, the largest power dam in the world extends for nine-tenths of a mile from the Illinois bluffs across the river to its junction with the

THE KEOKUK DAM, LOCK AND DRY DOCK

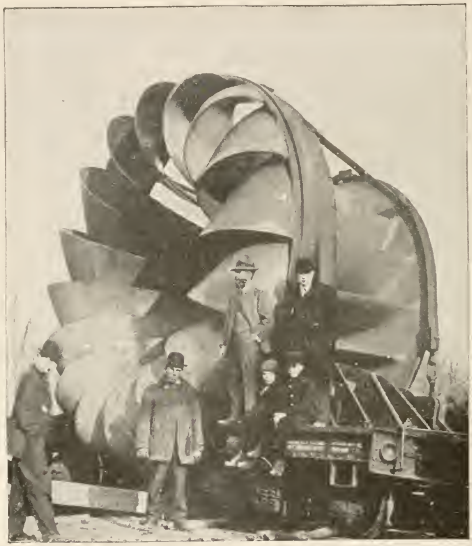


The Keokuk waterpower just previous to its completion, showing the dam stretching across the Mississippi to the power house which extends down the river to the government lock in the foreground. Between the lock and the reader is the dry dock partially completed. This lock and dry dock belong to the United States after being completed at the cost of the company.

The world's greatest power dam built across the Mississippi to join the power house in the distance on the Iowa side of the river.

The colossal Keokuk lock in the Mississippi as wide as those at Panama and with a higher lift than any one lock on the Isthmus.

power-house near the Iowa side of the Mississippi. The power-house extends down the river and is one-third of a mile long, half a city block wide, and as high as a fifteen-story building. At the lower end of the power house, between it and the Iowa shore, is the great lock, as wide as those at Panama and with a higher lift than any of them. Between the lock and the west bank of the river is the mammoth dry dock in which boats are built and repaired. The upper end of the forebay is closed with a massive concrete drift skimmer. The total length of the work is ten feet less than two and one-half miles; all solid concrete. The concrete masonry is set down into the hard limestone bottom of the Mississippi river, which was excavated for that purpose inside cofferdams, one of which enclosed thirty-five acres.


One of the thirty titanic turbines of the Keokuk water-power plant, several times as large as any ever built before. It weighs several hundred thousand pounds and revolves with the power of ten thousand horses.

The dam is fifty-three feet high, forty-two feet wide at the bottom and twenty-nine feet wide on top, and consists of 119 arched spans, between the piers of which are spillways over which the water flows; each spillway being topped by a huge steel gate. The lake above the dam has an area of over one hundred square miles, and its surface is kept constantly at the same height by opening or closing gates in the dam as the stage of water in the river changes.

THE GIANT POWER HOUSE

The power house has thirty identical units, each composed of a gigantic water wheel connected by a shaft with a mammoth electric generator above it. Each of these wheels is over four times as large in dimensions as any ever built before. They were hauled on a car built for the purpose, after the water tank spouts and coal chutes had been removed along the route from the foundry in Ohio to Keokuk. From the largest generators ever built the electric current is conducted through immense transformers which step it up to 110,000 volts at which pressure it goes over the transmission line to St. Louis and intermediate cities. This transmission line consists of six large copper cables supported on steel towers standing on concrete pillars. The total power developed on the water wheel shafts is 300,408 horsepower, and after deducting losses there remain 200,000 horsepower to be used in manufacturing. The power developed in that one power house is greater than the total water-power generated in any state in the Union save three—Maine, California and New York.

THE WONDERFUL LOCK GATES

The features of the lock are the result of its exceptional size. The lower gates weigh a million pounds and the sag strain on the top of the hinges is 364,000 pounds in each of the two gates. Yet they move so easily that only a little force is required to swing them open or shut, and they meet in the middle of the lock so perfectly that there is no more leakage of water than the quantity one may wring from a pocket handkerchief. The upper gate is a marvel of mechanical engineering and is a basically new invention in lock gates. The work has attracted the attention of economists on account of its great effects on the Middle West and the entire Union by its influence on manufacturing. Most of the water power in operation in the United States is around the borders of the country and is used chiefly for lighting and traction power because its distance from raw material and markets lessens its value for manufacturing purposes.

DISPOSAL OF THE ELECTRICITY GENERATED

This Keokuk water power of colossal size is in the very center of the populous Mississippi Valley where its electric power is especially available to energize machines in factories. It is intended specifically for that use. It produces many times enough power to supply the manufactures now in its sphere of influence, and a vast amount of manufacturing must be moved into its power zone to consume the electric current now produced. The transmission lines run to Burlington, Iowa, 40 miles to the north and to St. Louis, 150 miles to the south, tapping intermediate cities. The current is specially available at Keokuk, Iowa, and Hamilton, Illinois, at the opposite ends of the gigantic work.

A NEW INDUSTRIAL DISTRICT IN THE COUNTRY'S HEART

The proprietary company recognized that its large quantity of power could not be sold quickly to factories brought into the power zone and early began a campaign to build up a new industrial district in the heart of the country. To this end it is assisting each of the cities in the power zone to make themselves attractive to manufacturers and factory operatives. It is based on the greater economy in electric power produced by water over steam power produced by coal. Though located in the midst of the cheapest coal in the world it will more than meet the competition of that coal in its prices for power.

EIGHT MILLION TONS OF COAL SAVED YEARLY

This Mississippi water power conserves for other uses than manufacturing over 8,000,000 tons of coal yearly. It will make a new manufacturing center for the United States and start a new industrial era for the already rich Mississippi Valley.

MARVELS OF UNDERGROUND ENGINEERING

OF all the problems which have confronted the engineer during the past twenty years, none has been more persistent than that of the relief of traffic congestion in our great cities.

City after city has discovered, when the cost of acquiring property at surface has become prohibitive, that its main traffic arteries are hopelessly faulty in design for efficient service; and the false expedients which have been devised for relief, only to present new and more difficult problems, are too familiar to need enumeration.

Surface congestion

There are three types of congestion—pedestrian, passenger vehicular, and freight vehicular, the last two being capable of further subdivision.

In many cities the congestion on the footpath itself is so great that walking is a waste of time. In parts of the City of London an hour's hard walk at noon would accomplish less than a mile and a half.

Each large city presents a different problem for solution, as the result of the conditions which have governed its growth. London's chief problem has been to secure a passenger transport service connecting the districts, constantly expanding north, south, and west, with the city business center and the busy port to the east.

In Paris the problem was partly a military one. It was necessary to secure intercommunication between isolated suburbs set radially about the center, both within and without the fortifications, as well as to make possible the rapid concentration of troops to any part of the defences.

Boston and Philadelphia have comparatively short subway systems for passenger traffic—particularly Philadelphia—in Chicago, following on the extension of the railway system of America, it became imperative to find some means of handling the freight transfers of the twenty-five great trunk lines which meet there.

New York City has had to face the most difficult problems of all. Here the original city, situated on the long and narrow Manhattan Island, has extended southeast over the southern portion of Long Island (owing to port facilities) and west, on to the mainland around the termini of the trunk lines which serve the continent. The problem in New York was that of establishing intercommunication north and south along the axis of Manhattan Island, and east and west across the broad East River to Brooklyn, and the great estuary of the Hudson to Jersey City on the mainland.

Elevated railways

The first attempts to relieve congestion of traffic at surface took the form of elevated railways, and those of New York and several continental cities are models of ingenuity in construction. These, however, except in those cases such as the Barmen-Elberfeld Monorail, where they can be constructed over existing water courses, invariably introduced other undesirable conditions.

The early subterranean railways (such as the London Metropolitan and District) were constructed on the cut-and-cover system. Steam was the motive power used by the trains, and the use of fire under the boiler, with the attendant smoke difficulty, made large tunnel sections and frequent communication with the open air imperative.

The conditions which have led immediately to the construction of relatively deep tunnel communications have been accurate geological knowledge of the continuity and thickness of certain soft strata, and the march of physical science in the department of electricity, combined with the ingenuity of the engineer in following closely the discovery of scientists in both domains, and bending them to service in his work of construction.

It must not be imagined that all cities can be provided with such an admirable system of deep level underground communications as London has. Had it not been for the existence of the stratum known as the London clay, which overlies the chalk and lower London tertiaries, the construction of such communications, if they existed at all, would have been on the cut-and-cover system, to take advantage of the soft subsoil. Economic considerations would have made them far more limited in extent, and great inconvenience in the way of traffic dislocation during their construction.

In the Paris Metropolitan and the New York subway, we find typical cut-and-cover work, and the London County Council tunnel under Kingsway is an excellent example of the type of such construction. The necessary arrangements for traffic diversion, and acquirement of surface property, add enormously to the cost of an undertaking of this kind.

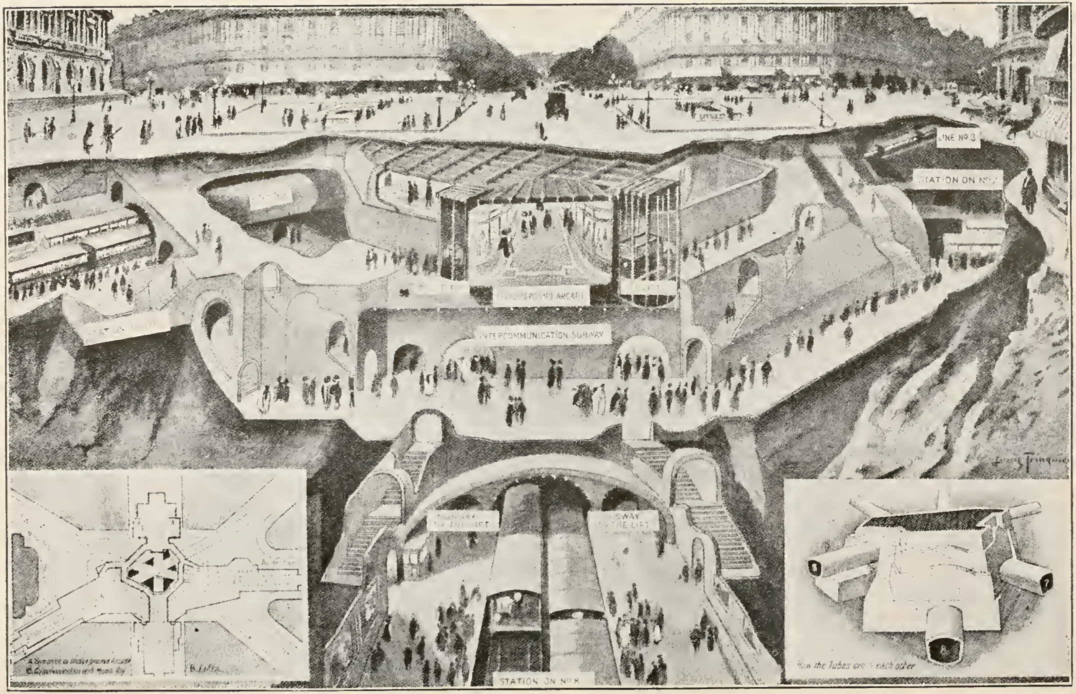
Both Paris and New York present the same difficulty of rock at or near the surface with a certain thickness of subsoil and surface gravels to help out. A large proportion of the New York subway had to be blasted from the solid rock. New York has the added complication of the necessity of carrying the tunnels beneath wide and deep river channels.

London and Chicago are related, in that each is underlaid by a thick substratum of plastic clay and an admirable medium in which to construct deep underground communication; but the problem in the one case has been the transport of passengers, and in the other that of freight.

Chicago possesses some sixty or seventy miles of underground railway on which not a single passenger is carried, the work of transport being confined to mails, merchandise, coal, and rubbish. The track serves every street in the business district, and a great deal of the residential quarter. Goods for delivery to the railway termini or other parts of the city are sent to the nearest collecting station and conveyed over the railway system. Ashes and coal are collected and distributed in the same way. The mail bags are handled on mechanical elevators, from the subway into the post-office building and vice versa, and the streets are relieved of freight traffic to the extent of about 30,000 tons daily. Large business houses have private elevator shafts from the basements to the subway below. In recent years, wherever a large building has been erected, a temporary shaft has been constructed to the subway, and all the excavated material from the foundations has been fed straight into cars below, at an average depth of 45 feet below the surface.

The tunneling for Chicago's freight railway was carried out at the rate of some 300 feet per day, and the excavated material added a park of over twenty acres on the lake shore to the city's open spaces, free of cost to the community.

It was originally intended to operate the King William Street and Elephant and Castle subway, London, by a steel cable. Following on the successful construction and operation of this subway, it was for the first time generally realized that, conditions being similar under the whole of London, a network of subterranean rail-



HOW THE GROUND BENEATH A GIANT CITY IS BURROWED LIKE AN ANT HILL

The Illustration shows what is taking place beneath the Place de l'Opera at Paris. Perhaps in time the dream of the imaginative novelist may be realized, and a great part of a city's population will not only travel but dwell in the netherworld.

ways was possible, to deal with the passenger traffic problem in every part of the city and suburbs. The year 1893 saw the construction authorized of not less than six separate tubes.

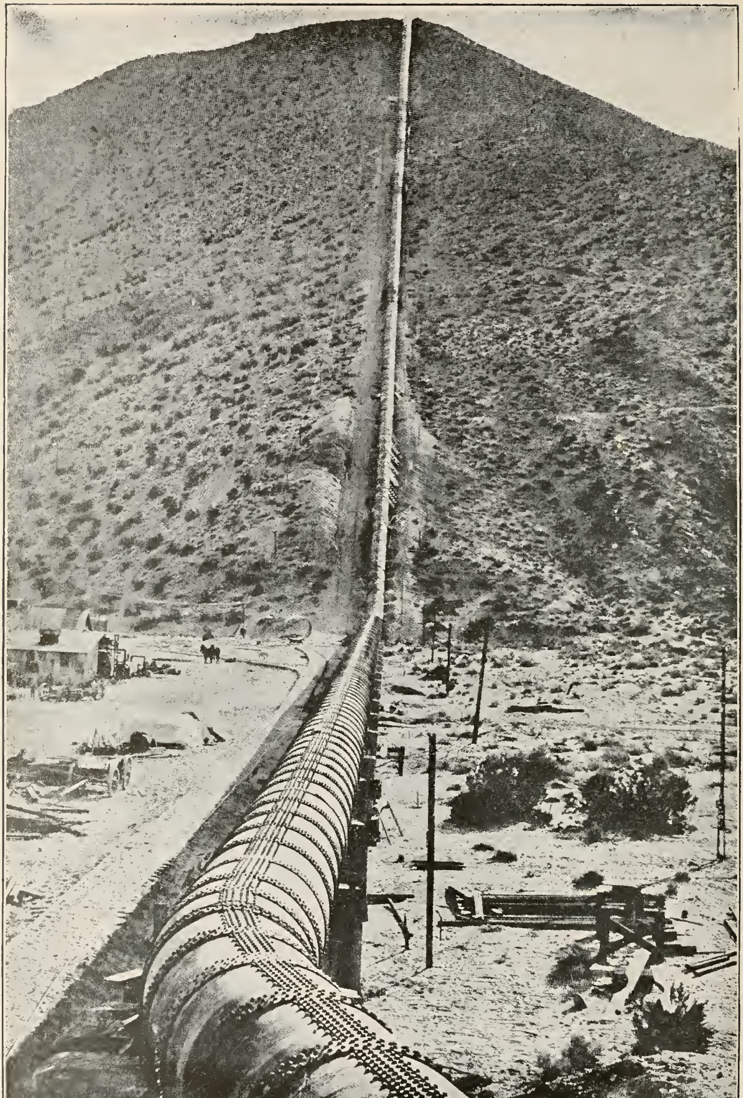
It is comparatively easy today to build subways, even when their construction involves tunneling under the beds of great rivers. But when the Pennsylvania Railroad tunnels under the North and East Rivers, ninety-seven feet below high-tide level, were bored from the New Jersey shore across to and under Manhattan Island and thence to Long Island there was no engineering precedent for the undertaking.

The tunnels or tubes themselves consist of a series of iron rings, and the installation of every ring meant an advance of two and one-half feet. Eleven segments and a key piece at the top complete the circumference, and an entire ring weighs about fifteen tons. The cast-iron plates, or sections of the ring, have flanges at right angles to the surface, and it is through these that the successive rings are held together with bolts. The record progress in one day of eight hours was five of these rings, or twelve and one-half feet. Hydraulic rams, placed against the flanges every few inches around the tube, were used to push forward the huge shields with which the tunnels were bored. This type of shield weighed 194 tons.

Longest, if not the largest, of the holes burrowed under New York by human moles is the great water tunnel through which the mountain streams, impounded by the Ashokan dam and brought to the city's edge by the Catskill aqueduct, will be distributed through the five boroughs. There are four distinct types of aqueduct, cut-and-cover, grade-tunnel, pressure-tunnel, and steel-pipe siphon, north of the city line. The city aqueduct, through which Catskill water will be distributed, is a circular tunnel in solid rock, fifteen feet in diameter at the upper end and reduced to eleven feet in the outlying boroughs. From two terminal shafts in Brooklyn steel and iron pipe lines will extend into Queens and Richmond. A cast-iron pipe, resting on the harbor bottom, will cross the Narrows to the Silver Lake reservoir on Staten Island, holding 400,000,000 gallons. The total length of this delivery system is over thirty-four miles. The tunnel has depths of 200 to 750 feet below the street surface, thus avoiding interference with streets, buildings, subways, sewers and pipes. These depths are necessary, also, to secure a substantial rock covering to withstand the bursting pressure. The tunnel construction involves twenty-four shafts, about 4000 feet apart, located in parks and other places where they interfere very little with traffic. Through these shafts, also, the delivery of the water is accomplished through additional pipes.

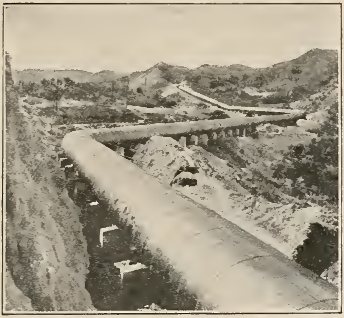
One of the most remarkable of such undertakings is the great aqueduct which traverses no less than 246 miles to supply Los Angeles with water.

Determined to secure a supply of the purest water obtainable, the enterprising authorities of this American city have tapped a source high among the mountains of the Sierra Nevada. From that distant place a crystal river will flow through divers conduction agencies before it reaches the water-taps of city consumers. For over twenty-two miles its way lies through a canal; a conduit covered with concrete conveys it for 164¼ miles. More than ten miles of tunnel have been painfully delved through earth by human moles to provide a passage-way for it, while eighteen and one-fourth miles have been hewn and



THE JAWBONE SIPHON

The Jawbone Siphon is the most remarkable in the world. Varying between 7 and 10 feet in diameter, it has a total length of 8135 feet, and weighs no less than 3243 tons.



THE EASTERN HALF OF SOLEDAD SIPHON

The Soledad Siphon 8060 feet in length, with its diameter of 11 feet, so big that a motor-car can be driven through it without grazing either side.

blasted in the solid rock. In addition, there are nearly two miles of steel flume, the cleansing reservoirs extend seven and one-half miles in length, and the engineers can take advantage for twelve and one-half miles—roughly one-twentieth of the entire distance—of the natural bed of a stream.

Great as this achievement of delving and blasting and adaptation of existing means undoubtedly is, it pales into insignificance beside the means employed for nine miles of the way, by which the stream sufficient for a population of two million souls is carried over mountain tops and down the sides of deep valleys. To cope with such difficulties the engineers realized that it was necessary to employ the siphon principle. Never before has so much mammoth steel piping, capable of carrying three hundred million gallons of water per diem, been employed for such a purpose. The Jawbone Siphon is the most remarkable in the world.

UNDERGROUND LIFE OF THE BIG CITIES

From a million and a half to a million and three-quarters of the residents of New York City spend at least a portion of each day underground, and many thousands come to the surface so rarely that the light of day blinds them when they reach it.

According to the best obtainable statistics about 20,000 persons in New York City spend their entire working hours beneath the surface of the earth.

These figures are not the sort that deceive. They are figures of fact, conservatively given, and if in any manner incorrect, they err on the side of conservatism.

On quite ordinary days 1,500,000 persons are accommodated in the New York subways, and the crowds are multiplying week by week.

Men go below the surface to reach the trains that are to take them from the architectural wonder, the new Pennsylvania Station, east and west out of the city. After they have reached the trains they are dropped still further underground, in order that they may pass beneath the bottom of the Hudson and East Rivers.

To get out of New York City by means of the New York Central Railroad or the New York, New Haven and Hartford Railroad it is necessary to make use of that other architectural wonder, the Grand Central Station, and again travelers drop down into the bowels of the earth before they may start.

The Lackawanna Railroad, not to be outdone by its rivals, advertises that "Miss Phoebe Snow" may now travel from Thirty-third Street to Buffalo, and to do that must go down into the earth and under the North River to make her start.

All of this underground business sounds dingy and dirty, but in reality there is much that is clean, bright and attractive about New York's underground world. The new Pennsylvania

Station, to which reference is made by way of illustration, covers more territory than any other building ever constructed at one time in the history of the world. From beneath its wonderful dome trains pass out under the North River to start on their 2000 mile trip into the west, and other trains travel eastward far beneath the surface of Manhattan Island, then out under the East River into Long Island.

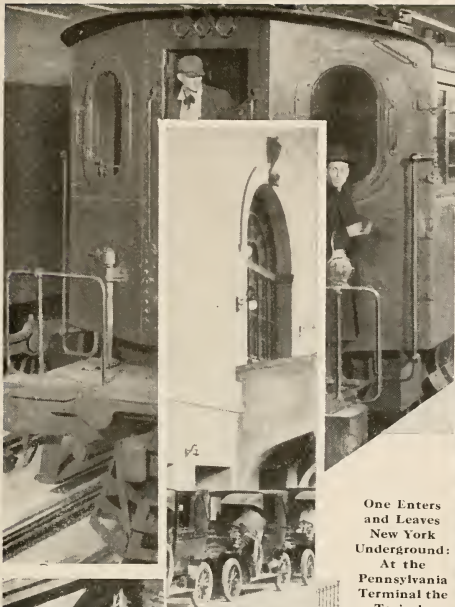
Wonderful and beautiful as the Pennsylvania Station is, it has a fair rival in the new Grand Central Station, only recently opened to the public.

Practically every skyscraper in New York City, and they are numbered by the hundreds, adds its quota to the "underworld" population of the city.

Before the greater structures—those that rear their way thirty, forty and fifty stories into the air—are really started, their foundations are sunk far down into the living rock which forms practically all of Manhattan Island. In many cases very comfortable apartments are to be found forty or fifty feet below the street surface, and there families are raised, children growing to maturity without ever having known the comforts of a home above ground.

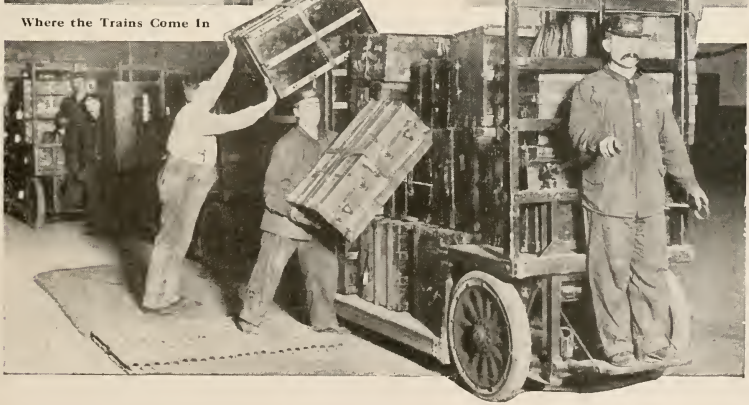
Practically all of the great newspapers of New York City have their batteries of presses below the surface of the earth. Some of them, notably the Herald, so arrange their windows as to make their pressrooms visible from the sidewalks, making them show places that attract tens of thousands.

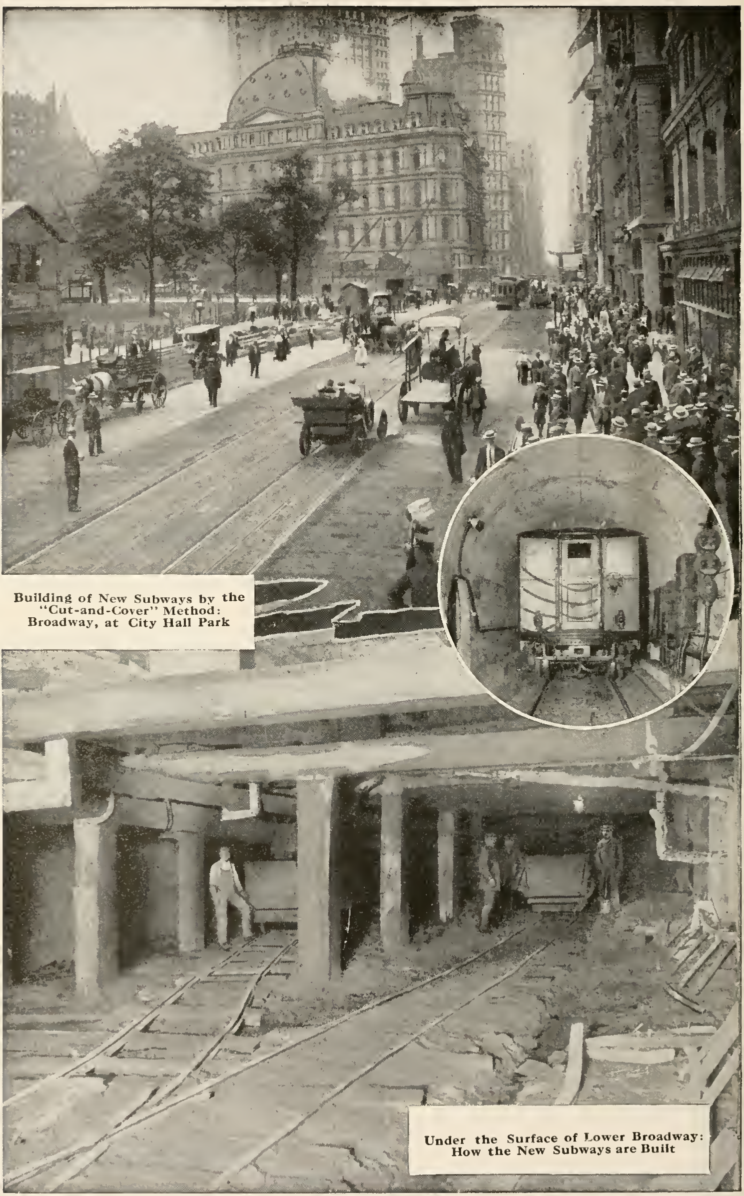
In the great hotels of New York the mechanical departments are all far beneath the street surface. These departments are well worth visiting, and in most cases the hotel proprietors are only too glad to permit their kitchens, bakeshops, furnace rooms, enginerooms, and laundries to be inspected. These places ordinarily are the cleanest in the entire hotel.



One Enters and Leaves New York Underground: At the Pennsylvania Terminal the Taxicabs Plunge Underground Like Moles and Moving Staircases Make Climbing Easy

Where the Trains Come In





Building of New Subways by the "Cut-and-Cover" Method: Broadway, at City Hall Park

Under the Surface of Lower Broadway: How the New Subways are Built

Then, too, in most of the more expensive hotels the grillrooms are below stairs. On these rooms and in these rooms fortunes are spent by the proprietors and their patrons. A few years ago fashionable New York refused to put its feet below the street level. Now it goes willingly into the basement, there to nibble at delicacies and sip vintage wines for which it pays exorbitant prices, the while listening to high - salaried cabaret performers who are assisted in their performances by world-famous orchestras.

Many of New York's greatest department stores are connected directly with the subways, as are also some of its newer theaters. A party once visiting in New York, lived for a fortnight in one of the most fashionable and most expensive hotels in the city, spent most of their time shopping, sight-seeing and theater-going, and only once during the entire fourteen days passed into the open air of the outside world. From their rooms in the hotel they were dropped by elevator to the level of the subway. Through the subway they went to department stores, theaters, restaurants, museums and even to church. When they started for home they went by subway from their hotel to the Grand Central Station and did not get out into sunlight until their train had well started on its journey.

While the underground development of New York has progressed farther than that of any other city, yet the inevitable tendency, wherever population becomes congested and land values high, is to utilize the subterranean areas for business purposes. In London, where the skyscraper has never found favor, a very marked development downward is now in progress. The new County Hall, which is slowly assuming shape and substance

ONE OF THE EXPENSIVE GRILL ROOMS FAR BELOW THE STREET LEVEL IN NEW YORK on the south side of the Thames Embankment, is one of the many new buildings in London remarkable for their underground space, and every year sees extensive additions to the underworld of London, where the abnormal demands on space have evolved the underground man.

Paris, too, has a highly interesting underground life. Unique among cities in many respects, in none is it so remarkable as in its great sewer system, which for years furnished hiding places for criminals and secret passageways utilized by many for transit between different parts of the city. Now the subways of Paris have become the most popular means of travel in the French capital. There are eight subway lines in all, and their popularity is due to the small expense of traveling, the quick and efficient service, and the convenient system of "change" stations permitting transit from any one part of the city to any other for the same price.

Boston and Philadelphia have progressive and impressive subterranean railway systems for passenger traffic; but New York, where every inch of excavation must be blasted out of solid rock, has however, developed the human mole to a greater degree than any of them.

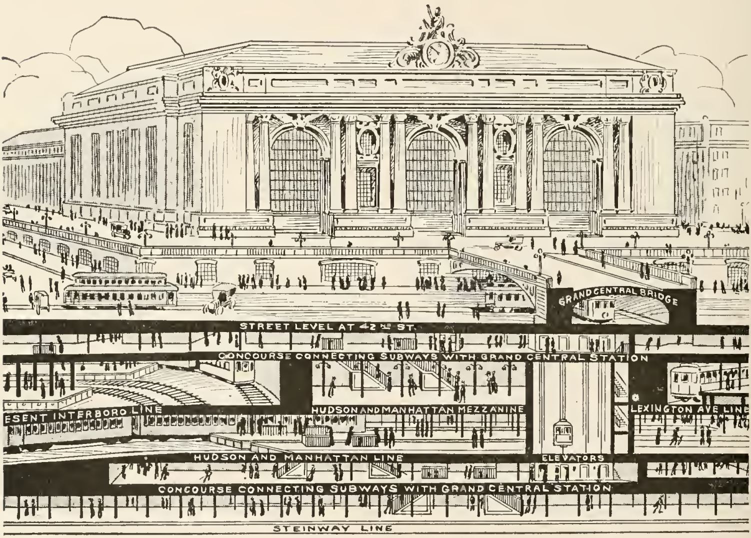


DIAGRAM SHOWING THE DIFFERENT SUBTERRANEAN PASSAGES AND TUNNELS EXCAVATED AT THE GRAND CENTRAL STATION BY NEW YORK'S HUMAN MOLES

SPAN OF THE NEW BRIDGE OVER HELL GATE, NEW YORK

FOOTPATHS IN THE AIR

NO one can say who built the first bridge. Nature herself would no doubt be man's first teacher. Man would find a path across a chasm by clinging to a twisted vine; or he would see a ready-made bridge consisting of a fallen tree-trunk across a stream. Those were the first bridges, and they were the sort which would have to be made for hundreds of years.

One day a genius arose, who dumped high heaps of stone in a line across a stream, and on the top of these placed slabs of slate or stone or fallen trees. Then, a long, long while afterwards, came real bridges. The Romans were the first to learn how to make these. They built splendid bridges on arches, some of which exist today.

A great reform was made in bridge-building by John Rennie, an engineer and architect. It had been customary to make the arches very high, so that the roadway sloped sharply up on one side, and very sharply down on the other. But Rennie made his arches, not like the half of a circle, but like the half of an egg, cut lengthwise.

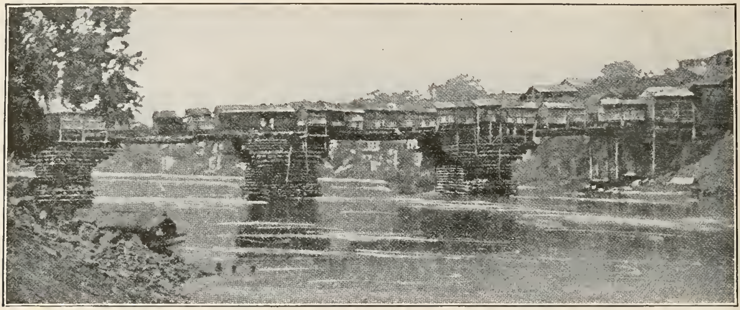
There still exists a famous single-arch bridge of the old type, the famous bridge at Pontypridd, Wales.

When the eighteenth century was drawing to a close, men began to build bridges of cast iron. But engineers soon found that, though cast iron can bear great pressure, it will not bear much pull. It cannot be easily crushed by a weight, but it can soon be snapped by weights which pull at the two ends. So then they used wrought iron, which cannot easily be pulled apart. That served until steel came into use in the nineteenth century.

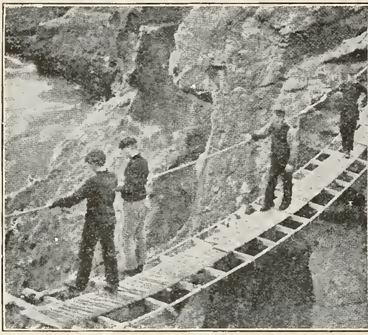
It is over the Hudson River in New York and over the St. Lawrence in Canada that man has gained his greatest victories in spanning wide expanses of water with gigantic steel roadways. It must not be forgotten that Great Britain has many fine examples of the bridge-builder's art; the Royal Albert Bridge at Saltash, the Britannia Bridge over the Menai Strait, and the Forth Bridge, whose span of 1700 feet has yet to be eclipsed, may be quoted as daring and remarkable bridge-building feats.

The first great bridge built of wrought iron was the Britannia Bridge, in North Wales. The builder was Robert Stephenson. He made a huge square tube of iron—iron at the top, iron at the sides, iron at the bottom, and through this tube of iron the trains pass. To increase the strength of the bridge he made the

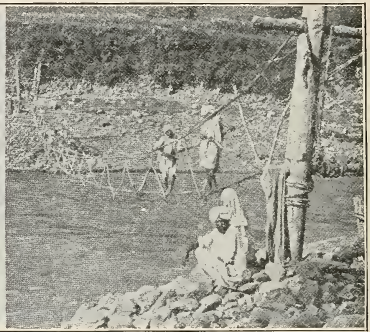
OLD-FASHIONED BRIDGES IN PICTURESQUE LANDS



This picture gives us an idea of what our bridges were like once upon a time. Here is one built on piers made of nothing but logs. On top there is a roadway of timber. This is the bridge at Sringar, the beautiful old capital of Cashmere, Northern India. The houses recall the bridges of old-time London with their shops and dwellings.

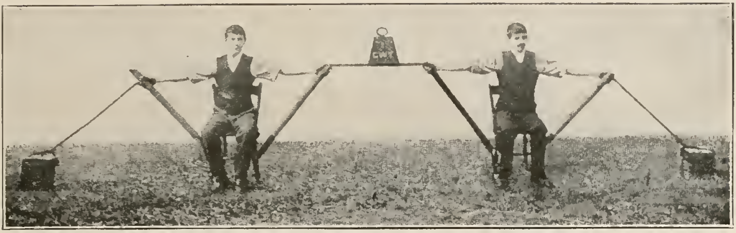


This rough-and-ready bridge serves for fishermen to pass to a rock off the coast of Antrim, Ireland. It consists only of strong ropes and staves of wood. In stormy weather it sways and needs courage to cross.

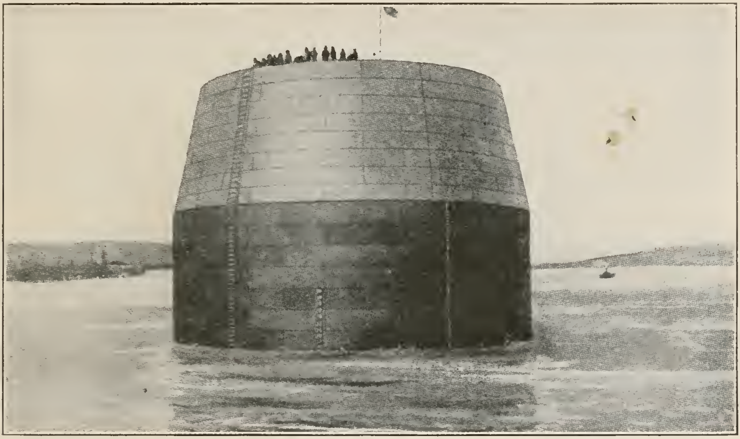


Tight-rope walkers should like this bridge. It is made up of three ropes. Two of the ropes serve as handrails; the third is the footpath. It crosses a river in India which has many modest suspension bridges like it.

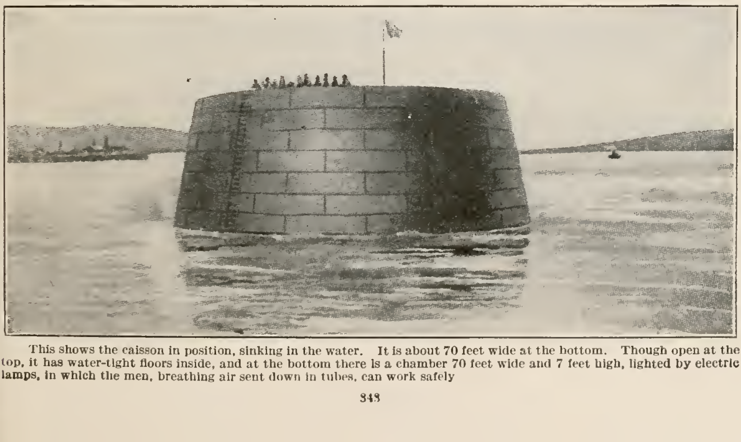
This is the sort of big bridge that we see where the single arch and cantilever are not used. It is the Iwakuni Bridge in Japan, a bridge of wood and stone, in four spans. Only small ships can pass under it, and the roadway is as steep as a switchback ladder, and is furnished with 200 steps. Horses and carts cannot go over it.



This shows us how the weight of a bridge is distributed; it illustrates what bridge-builders call the cantilever principle. These two men are sitting on chairs, each holding two sticks. The outside sticks are fastened to weights, and cannot move. The inner sticks are fixed to the chairs, and from their tops another stick is stretched, bearing a weight of 112 pounds. Yet the men feel no weight, and they represent two pairs of cantilevers.

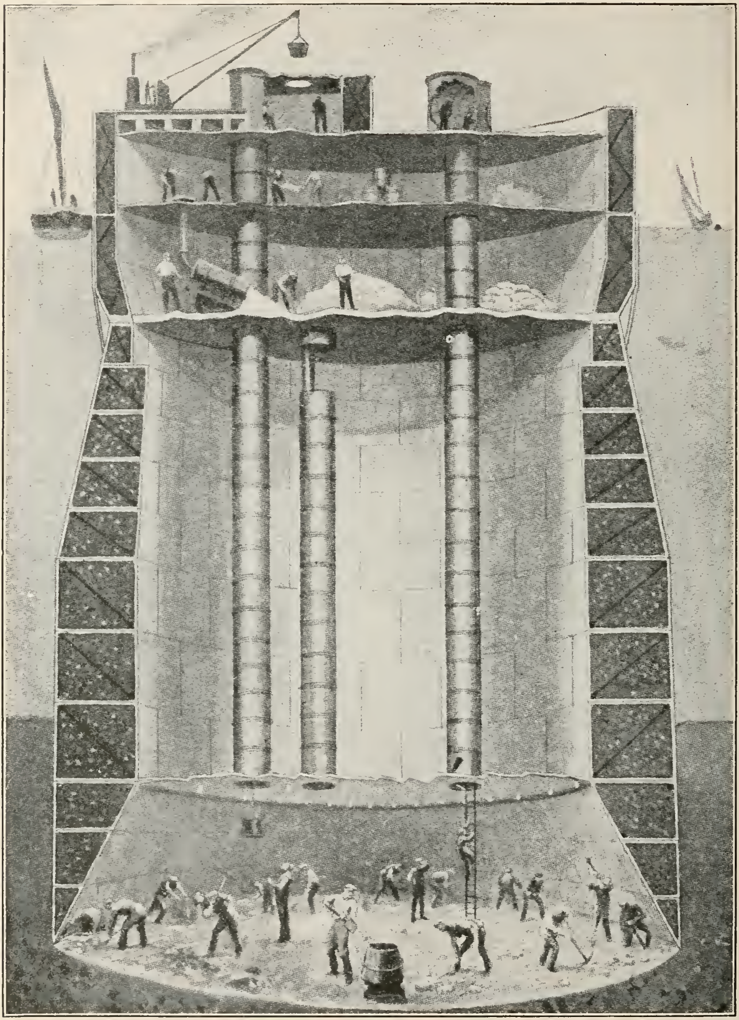


This is a caisson, like a great hollow chamber, inside which men can work to set up the foundations of a bridge. The caisson is here floated into position for the building of the Forth Bridge. The huge steel tubes reach down to the bottom of the water, and men work inside them without danger, as if in a workshop.



This shows the caisson in position, sinking in the water. It is about 70 feet wide at the bottom. Though open at the top, it has water-tight floors inside, and at the bottom there is a chamber 70 feet wide and 7 feet high, lighted by electric lamps, in which the men, breathing air sent down in tubes, can work safely

THE INTERIOR WORKSHOP UNDER THE WATER



This shows us the inside of a caisson while the men are working. We can see the tubes leading down from the top to the working chamber at the bottom. Inside one tube is a ladder by which the workers climb up and down. Other men bring down material and take up the broken rock which has been dug. Another tube brings down air for the men to breathe. If the bed of the river is muddy the mud is forced away by the compressed air. Water is kept out of the chamber by compressed air which is made to press with greater force than the water. From top to bottom the caisson is 60 feet deep and inside it is like engineering works.

iron at the top and bottom tube-shaped, instead of solid, because it would better stand the pull of the weight.

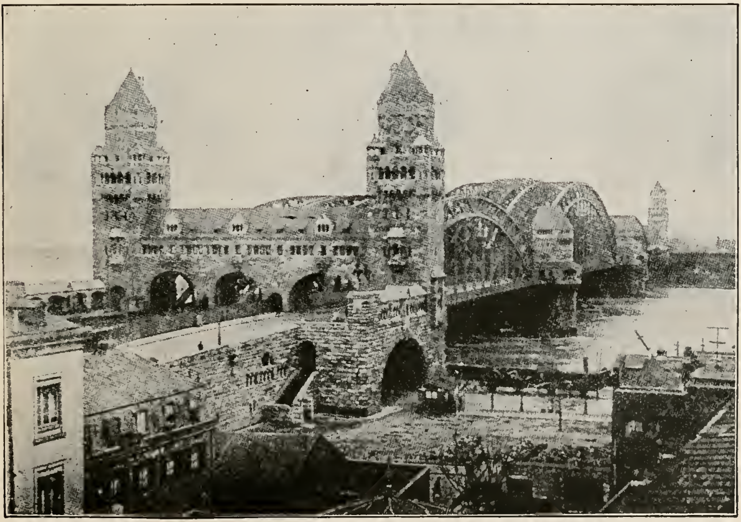
THE GREAT IRON TUBES IN WHICH THE TRAIN CROSSES THE WATER

These tubes are built on huge columns of masonry, one built on an island half-way across the water, and the others on the land at the sides. As ships were constantly passing, it was impossible to put up great scaffolds on which to build up the ironwork. So Stephenson had the two tubes, nearly 500 yards long, built in four sections on shore. When all was ready the big tubes were floated on many boats, and ferried out to the the towers.

As the tide went out the boats gradually sank, and the tubes, weighing 5000 tons each, came to rest in grooves prepared for them in the masonry. Then the boats were drawn away and the enormous masses of iron were hoisted up to the proper height, 100 feet above the water, by great engines.

The finest of all bridges is the great steel cantilever bridge. A cantilever is copied from the oldest of simple bridges. If two trees lean over the water from different sides of a stream we have only to run a plank from the end of one trunk to the end of the other, to make a simple cantilever bridge. That is one way of applying it. The other is to consider the cantilever a bracket. Secured firmly at one end, a bracket will bear a shelf with a heavy weight of books, and the steel cantilevers forming a bridge are merely huge brackets. The best example is the great Forth Bridge.

The Forth Bridge was designed by Sir John Fowler and Sir Benjamin Baker. They had to cross two swift channels of water. There is an island in the middle, but on each side of it there flows a channel of water deep and swift,



MODERN STEEL BRIDGE ACROSS THE RHINE AT COLOGNE

When the rock had been prepared for the foundation of the Forth Bridge, strong masonry was built from the rock below the water up to the top. Then huge pillars of hollow steel, such as we see here, were put up for the cantilevers, and were fastened down to the masonry with enormous steel bolts. They are 343 feet high, but so strong that neither the weight and vibration of great trains nor the force of storms can break them.

The giant pillars having been made fast, the cantilevers began to grow out from them. Each of these is really a double cantilever. They stand like brackets back to back. Perfectly balanced, they stood firm while the engineers built out into the air from them, as if they were brackets fixed to the walls, bearing heavy shelves.

and 1700 feet broad. It was impossible to sink piers in these channels, so the central pier was founded on the island, and two others built nearer the shores.

The cantilevers, of which there are three pairs, carry the bridge across the two wide stretches of water. They are each 1360 feet long, and the three, stretching out towards each other, leave a space of 350 feet to be covered between the ends of the first and second, and a similar space between the ends of the second and third. Here ordinary steel girders are used. In order that ships may pass under it, the bridge is made 150 feet above high tide, and its top parts are 361 feet above the water.

The cantilever bridge plan has since been used for many other bridges. One on this plan crosses Niagara at a great height above the water. The cantilever is used in suspension bridges also. Huge columns are erected on land, and from them chains or wire ropes are stretched across the gulf, carrying a roadway.

HOW KITES AND ROCKETS ARE USED FOR BUILDING GREAT BRIDGES

The best suspension bridge in England is at Clifton. This is 702 feet across, and 31 feet wide. It is more than 200 feet above the River Avon, and it is said that the first string attached to the rope which pulled across the cable was sent over by a kite.

A more unusual way was adopted for starting the great bridge across the River Zambesi, in South Africa. The bridge is the highest in the world, 400 feet above the water, and runs from cliff to cliff; so they had to fire a rocket fastened to the end of a cord. The rocket took the cord across, the cord was used for hauling across a wire, and the wire was used to pull over a small cable. On this a truck crossed carrying the main cable of the bridge, which is 200 yards long, and the greatest engineering wonder in South Africa.

The Tower Bridge, in London, is 800 feet long. When a ship is too high to pass under, great machines cause the roadway to open in the middle. The two halves are pulled up, working on enormous hinges, and the ship passes through.

The Saltash Bridge which spans the Tamar is 2200 feet long, the two main spans over the river being each 455 feet long. The height of the central pier from its foundation to the top is 240 feet, and the railway track is carried 110 feet above the level of the water. Obtaining the foundations for the pier was a particularly dangerous piece of work. A huge caisson was sunk in midstream, in which, provided with compressed air, the men toiled for two years. In the winter storms the unwieldy cylinder rocked so violently despite its heavy weights and chains, that leakages occurred, and it was only by beating hasty retreats that the men escaped drowning. The two gigantic spans were built complete upon the shore and floated out into position, and then gradually raised to the desired height, three feet at a time at each end by means of hydraulic presses.

For the finest and latest examples of the bridge-builders' skill we have to go to New York. Here, in space of a single square mile we have the three greatest suspension bridges in existence—the Brooklyn, the Manhattan, and the Williamsburg bridges, while some three miles above the last-named there now towers Blackwell's Island Bridge. They are rightly regarded as among the wonders of the engineering world. They vary from 6000 to 7000 feet in length, with a central span of from 1400 to 1500 feet, and carry four tracks for railways, two

THE WONDERFUL ROAD THAT A MAN CAN OPEN

The Tower Bridge is the most beautiful in London. It is like the old-fashioned draw-bridge which castles and fortresses had, only much larger and stronger. It is called a bascule bridge, "bascule" meaning "balancing." This picture shows what happens when the great roadway opens for big ships to pass along the Thames. Each half rests on a pivot and is balanced by an enormous weight at the tower end. When the bridge is to be opened a man pulls a lever which drives water at great pressure through a pipe and so turns a series of cog wheels. The wheels move a number of curved frameworks with cogs and the two halves of the road each weighing 730 tons, turn slowly on their pivots. The roadway at the top is always in use and is for foot passengers.

or more for cars, a couple of roadways for vehicles, and various sidewalks for pedestrians, while the towers reach a height of 300 feet and more above the water, the aerial pathway being some 130 feet above the surface of the river.

The Brooklyn Bridge took thirteen years to build, and cost $16,000,000. It was designed by John A. Roebling, the builder of the Niagara Falls suspension bridge and others. While engaged in the preliminary work he met his death. He was succeeded by his son, William A. Roebling, who in turn was injured by a fire in one of the caissons and became a permanent invalid. He was removed to a residence on the heights of Brooklyn, where, with indomitable resolution, he watched the details of construction from his window by the aid of a telescope, and, assisted by his wife, directed the progress of the work to its successful completion.

It is impossible to point to any large bridge the erection of which has not demanded its toll of human life. The recently completed Blackwell's Island Bridge cost 67 lives; some 70 brave men were killed in the Quebec disaster in 1907, when that partially completed structure suddenly collapsed after three years had been spent upon it, and some 15,000 tons of steelwork had been placed and bolted in position.

With its approaches the Brooklyn Bridge is a mile and a furlong in length. There is a central river span of 1595½ feet from tower to tower, two land spans from towers to anchorages, and the land approach on either side. This aerial roadway is held in place by cables, four in number. They each contain 5296 steel wires reaching from anchorage to anchorage, on either side of the river, a distance of 3752 feet. This gives a total of 14,000 miles of wire. Each cable has a diameter of 15¾ inches, and a breaking strain of about 12,000 tons. The roadway is 85 feet wide. The engineers declare that the "natural life" of the bridge is 20,000 years.

After the Brooklyn Bridge came the Williamsburg structure, which was erected in seven years at a cost of $20,000,000. It has a total length of a mile and 1920 feet, including a main span of 1600 feet, and two shore spans of 600 feet. The four cables are each 19 inches in diameter, and are built up of 37 strands, each strand containing 208 wires, each 3020 feet long. Figure this out and we get 19,000 miles of wire, possessing a weight of 5000 tons. The towers of this bridge rise 335 feet above the water level, and are built of steel. Somewhat similar in design is the Manhattan Bridge. The wire consumed here totals 23,000 miles, while no less than 40,000 tons of steel were used in the erection of this single aerial pathway.

More wonderful still, from an engineering point of view, is New York's latest structure, Blackwell's Island Bridge. In length and weight it rivals and in carrying capacity also surpasses the famous Forth Bridge. Its trusses are the heaviest ever built. There are two main spans of 1182 and 984 feet respectively, springing from two piers erected on a mid-channel island. From end to end the bridge measures 3725 feet, and, together with the approaches, the total length is swelled to 7358 feet.

In its erection the somewhat unusual course of pinning its members together, at points of intersection, was adopted, instead of riveting them. The truss members of the superstructure were not built up bit by bit near the site, but put together by the manufacturers and forwarded entire on cars or groups of cars, and pinned as the erection proceeded. A very

ONE OF THE FAMOUS SUSPENSION BRIDGES

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Brooklyn Bridge is one of the biggest suspension bridges in the world. It crosses the East River, to connect New York with Brooklyn The whole length of the bridge is more than a mile, and its distance across the water is 1600 feet. Cables pass over the towers and from these other cables hang down to support the roadway.

We might here fancy ourselves on some strange pier, but it is the Brooklyn Bridge. There are separate roads on this bridge for foot-passengers, for trains, and for other vehicles.

pretty bit of pinning it was too—the objects to be connected being bars and girders, some weighing 120 tons; the pins, cylinders of steel, some 16 inches in diameter and 10 feet long; the thimble, a 5-ton battering ram. And this work had to be done partly at a height of 300 feet above a deep, swift current, navigated by steamers, barges, ferries, and sailing ships, with the bitter winds raging furiously.

In the erection of this bridge, as stated, 67 lives were lost. Curiously enough, the great majority of these fatal accidents occurred among the sailors who had been engaged by the contractors because of their ability to climb. As a matter of fact, the successful modern bridge-builder must possess other qualifications than that of climbing. He must know something of steel, possess a clear head, and be ever on the alert.

But all this is to be changed. A bridge is being constructed which will have one base in the heart of Bronx Borough, just north of New York City, and the other at the Pennsylvania Station, Long Island City. It will span the East River. At Long Island City the tracks will run into the Pennsylvania Tunnel under the East River, and the trip to New Jersey under New York City and the Hudson River will be unbroken. This bridge is not being built by either the Pennsylvania or the New Haven.

The builders are the New York Connecting Railroad. Their six miles of railroad will form the final link in an unbroken line from Musgrave, Nova Scotia, to Key West, Florida.

The bridge will be of span and viaduct structure. It will have four tracks. The route will begin near One Hundred and Forty-Second Street, the Bronx, and gradually rise until at Bronx Kill it will be about sixty-five feet above the East River. At this point the river separates the Bronx from Randall's Island. The bridge here will be of the lift type; that is, each half of the bridge rises from the horizontal in a vertical plane so that ships may pass between.

The large stone pier in the middle of the Bronx Kill will separate the channels for east-bound and west-bound ships. At present the channel is very shallow and can be used only for rowboats and small launches, but the War Department intends to dredge the channel to the same depth as the Harlem River, so that vessels will be able to pass from the Hudson River to the Ship Canal in the Harlem River, and thence through the Bronx Kill under the bridge into Long Island Sound, and return the same way.

Another bridge on this long structure spans the East River at Little Hell Gate, as the estuary between Ward's Island and Randall's Island is called. The water at this point has a rock bottom so shallow that it cannot be plied by very large boats. The bridge here will be of the riveted-truss type and will have five spans between Ward's Island and Long Island. From this point to the span over Hell Gate, the waterway between Ward's Island and Randall's Island, the line will be placed on a steel viaduct built on masonry piers.

The arched bridge over the East River at Hell Gate will be of the braced-steel type and will cross the river in a single span 1017½ feet between the towers. The clearance at high water will be the same as that of the Brooklyn Bridge and the others over the river—135 feet.

The abutments will have a base of granite masonry surmounted by towers of molded concrete, which will support the heaviest girders. This structural steel will be much heavier than that used in the Firth of Forth Bridge.

THE PRODUCTION OF TEA, COFFEE AND COCOA

IN the days of Shakespeare tea cost from $30 to $50 a pound, and coffee and cocoa were practically unknown. It was about the middle of the seventeenth century that the three famous beverages, that "cheer but not inebriate," came into use among the richer classes of European society. The London coffee-houses, in which gathered the wits, poets, and politicians of London, in the days of Dryden and Congreve, Addison and Pope, were the centers of national life for many years. And from them sprang the clubs, around which many of the social, literary, and political activities of the civilized world are now grouped.

Very likely the new beverages greatly helped to foster all kinds of sociability, for the reason that they stimulated the mind without leading to the brawls and quarrels of tavern life. And the fact that they were at first rare and expensive was no doubt one of the reasons why they became extremely fashionable. Towards the end of the seventeenth century, the duty on tea in England was $12.50 a pound. So a "dish of tea" was a costlier thing than a glass of good wine. Human nature being what it is, everybody was eager to drink the new beverage. The East India Company began to send to China for tea. At first they had more of the new commodity than they could dispose of. But, as is often the case, the supply created the demand, and at the end of the eighteenth century the English-speaking races were second only to the Mongolian races in their love of tea.

But as the consumption was then only about two pounds of tea a year per head of the population, small beer and milk still remained the common beverages of the working classes. Cheap spirits, especially gin, were drunk by many poor women, with dreadful results. At the present time, practically all the civilized races have abandoned the breakfast drink of more or less intoxicating liquors for one of the three exotic stimulants that modern methods of industry have greatly cheapened in price, and often improved in quality. All the British races have become inveterate tea-drinkers. The Russians have acquired the same taste; and the very heavy duty on teas does not prevent the Russian working classes from adopting the same beverage as the well-to-do classes of their country. In Germany, Holland, and other parts of Northern Europe, and in the United States, coffee has become the general morning stimulant; while the French and the Mediterranean peoples waver between coffee and chocolate as a breakfast beverage.

THE COFFEE GROWING COUNTRIES

This national difference in taste has had a considerable influence on the agricultural and industrial development of the tea plant, the coffee shrub, and the cacao tree. In spite of the fact that all these plants are of tropical or semi-tropical origin and habit, the European nations interested in their products have attempted for centuries to cultivate them. Here the progress of European science, and particularly the science of botany, has had a large influence; and the peoples possessing tropical colonies or dependencies have often won a commanding advantage over the original cultivators. In some cases this was an inevitable consequence of the widening demand throughout Europe for the new commodities. For instance, all the coffee consumed in Europe used to come from the province of Yemen, in Southern Arabia. But as the number of coffee-drinkers increased, it was practically impossible for the Arabians to cope with the demand. They still retain the trade with Egypt and Turkey, and provide a little Mocha coffee for Europe. But in order to obtain a beverage that was both good and cheap, the Dutch and the Portuguese and the Germans have had to migrate to Java and Brazil, and there develop immense coffee plantations for the benefit of the white races.

WHERE CHOCOLATE COMES FROM

A similar thing has happened in regard to cocoa and chocolate. As is well known, cocoa was introduced into Europe from Mexico by the Spanish adventurers who conquered the bloodthirsty Aztecs. The cacao-tree flourishes in Central America and the tropical regions of Southern America. But the native Indians who collected the beans of the tree that Linnæus enthusiastically named "the food of the gods"—an appellation it still bears in botany—were too slow, casual, and unscientific workers. So the Portuguese introduced the valuable tree into their African possession of San Thomé, where, by means, unfortunately, of slave labor, more cocoa was lately produced than in any other center of the industry. At present, however, our principal supply of cacao comes from Ecuador.

THE TEA PLANTATIONS OF ASSAM AND CEYLON

But the most surprising of all the shiftings of the production of the breakfast-table beverages is that accomplished by the British. For more than a thousand years the tea industry was entirely in the hands of the Chinese. The origin of their supremacy in the production of the most refreshing of drinks is lost in the mists of their legendary ages. It is quite possible that three thousand and more years have passed since they took to cultivating the tea shrubs that flourish naturally in India, Burma, and other neighboring lands swept by the wet monsoons. The Chinese were a skilful, patient and ingenious race, backed by the traditions of an ancient civilization; and their knowledge of the preparation of tea was for a long time carefully kept from the foreigner, for it was one of the main sources of the national wealth.

But some botanists succeeded in studying the tea plant, and found it was an evergreen shrub of the same family as the camellia, that is well known for its beautiful flowers. Then it was discovered, in 1820, that the tea plant was growing wild in Assam, and the wild plant was sent to the director of Kew Gardens, near London, for examination. Unfortunately, the director would not believe in the plain evidence submitted to him; and he dashed the hopes of the men who thought of establishing tea plantations in India, by stating that the Assam shrub was not a true tea plant. It was not until 1840 that the facts of the matter were clearly and firmly proved, to the discredit of the director of Kew Gardens.

The Assam Tea Company was then formed, and by developing the scientific cultivation of the fine native Indian tea it has now paid its share holders nearly 750 per cent on their capital.

Introduced into Ceylon after the coffee plantations of that island were destroyed by a harmful microscopic fungus, the wild tea plant of Assam has now enabled the Ceylon planters alone to excel the tea exports of the whole of the Chinese Republic. When the tea industry of India, Ceylon, Burma and the Shan States is contrasted as a whole with the export tea trade of China and Japan, the swiftly won supremacy of the British planter is seen to be tremendous. The British possessions do more than double the export tea trade of China; and for some years a good many million pounds of Indian and Ceylon tea of poor quality have been imported into China.

The Japanese, who recently controlled practically all the tea trade with the United States, are also beginning to feel very keenly the competition of the British tea planter. They are now so hard pressed that they are giving up the struggle, and the taste for fine Indian and Ceylon teas is now rapidly spreading throughout North America.

The best of all teas

Only the plantations on the island of Formosa seem to be safe from the scientific attack of British botanists and planters. Formosan tea—known in the market as Oolong—has a curious and special flavor which tea-blenders prize. With the exception of Formosan tea and the maté tea of South America, India and Ceylon now produce teas of every practical variety. The choicest kind of Indian hill-grown teas are excelled by nothing that China exports, and for blends of cheap, strong, pure leaf the plantations of Ceylon are unrivaled. The Chinese themselves have had to go to India and study the science of the tea industry in order to learn to handle in a clean and efficient manner their own produce. The Indian tea plant has been introduced into Java, and there cultivated. Java is now combining with India and Ceylon in sending the refuse of their factories to Chinese ports.

The amazing agricultural victory which has been won against the experienced Chinese was achieved by three concurring factors. These factors were modern science, personal enterprise, and modern power machinery. Modern science, in the persons of a few botanists, discovered the wild tea plant of Assam, and thus provided planters with a stronger and more productive shrub than the highly cultivated plant of the Chinese. The leaf of the Assam shrub is twice the size of that of the Chinese plant; and when it is grown in the still, steaming heat of Ceylon and other tropical regions, it produces two crops where the Chinese plant only gives one picking. Such are the natural advantages of the plant that men of science discovered. The tea-planter began by adopting the Chinese methods of cultivation, for which the wild

CULTIVATION OF THE TEA PLANT IN CEYLON

PLANTING A YOUNG TEA SEEDLING IN RECLAIMED LAND

COOLIES HOEING ON A TEA PLANTATION

plant was unsuited. Again botanists came to his aid, and taught him how to treat the Indian shrub in a manner that best favored its growth.

Having thus learned to make the very best of his natural advantages, the planter then became a man of enterprise. He called upon engineers to provide him with power machinery for dealing with the tea leaves that the natives picked for him. This was a very wise act, and it required some foresight to conceive it. For the supply of native hand labor grew abundant and remarkably cheap, and it would have been easy to carry out all the

CHINESE FATHER AND SON CARRYING TEA

operations of preparing the tea leaf by means of manual work. But the tea-planters aimed at preparing an article that should be exceptionally clean, and treated with the utmost precision in every process, so that large quantities could be regularly turned out possessing identical qualities. So they began to use machinery; and the malpractices of a large class of their rivals in China further helped them to secure the world's market.

TEA GROWING IN CHINA

In the green-tea districts of China practically every cottager has his own little tea-garden. It supplies the wants of the family, and brings in a small but very useful amount of money. The picking begins about the middle of April. The first crop consists of scarcely expanding leaf buds, and the tea made from them is costly and exquisite. It is chiefly used in gift offerings at marriage. The plucking of the bud is liable to injure the plants, but usually the abundant spring showers renew the strength of the shrub, and in two or three weeks it is ready for the second picking. This is the most important of the season; but when the plant has again recovered, the third and last gathering is begun. This, however, produces an inferior variety of tea. The instruments used by the Chinese in preparing the tea leaf are very simple.

Quite a large proportion of the tea that comes from China is manufactured in the huts and sheds of the peasantry. Round, shallow pans of thin iron are built, several together, in a brickwork furnace. The fireplace is at one end, the rough chimney at the other, so that the flue runs beneath the row of pans. When the leaves are brought from the garden they are placed in a drying-house, which is often the cottage itself. The furnace is then lighted, and the leaves are thrown into the heated pans, and continually stirred by the cottager and his family. The heat causes the leaves to crack and exude their sap, and in about five minutes they grow soft and pliable. They are then placed upon bamboo tables, and the workers take up handfuls of the leaves, and knead them in much the same fashion as a baker works dough. The object of this process, that lasts about five minutes, is to twist the leaves and press out the sap and moisture, which escapes through the chinks in the surface of the table.

The moisture that still remains in the leaves is then gotten rid of very gradually and gently by taking the rolled leaves and spreading them out thinly and evenly upon a screen of bamboo, and there exposing them to the action of the air. The state of the weather determines this stage of the manufacture, but in no case is the screen exposed to hot sunshine. For this would evaporate the moisture too quickly, leaving the tea crisp and coarse, and unfit for the next process. This consists in replacing the soft and pliant leaves in the drying-pans over a slow, steady fire. The tea must not be scorched or burned. So one worker looks carefully after the fire, while the others bend over the pans and begin to mix and stir the leaves with their hands.

As the heat increases, small bamboo whisks are used, the leaves being thrown against the sloping sides of the pans and allowed to roll back to the bottom. Under this treatment the tea gradually parts with its moisture, and twists and curls; and after about an hour it is taken from the pans, and sorted and packed.

This is the process of making green tea. Black teas are allowed to stand longer in the open air, usually for two or three days. During this time they undergo a fermentation which does not take place in the manufacture of green teas. In the firing or final drying of black tea, great care must be taken to keep the heat steady. Usually the grandfather of the family, having the most experience, tends to the furnace, while his descendants keep the leaves constantly stirred in the pans.

Why some tea is green and some black

The scandal over the manufacture of Chinese teas occurred at Canton, where the green teas were mainly exported. In order to increase the color and brilliancy of the leaves, they were treated with gypsum and Prussian blue—a highly poisonous product. The tea-tasters at the London market, who had to sample very large numbers of consignments of these teas, were at times liable to attacks of poisoning. These were at first put down to heavy tea-drinking, and few tasters now swallow much of the beverages they sample. But chemical analysis proved that it was the poisonous coloring matter used by the Chinese that produced the serious illnesses.

No doubt at the present day the green teas of China are generally prepared for the foreign markets in this manner. But the injury to the reputation of the Chinese tea manufacturers has not yet been fully repaired. The malpractices have greatly helped to advance the prestige of the cleanly and scientifically prepared teas of India and Ceylon. In 1885, China exported 283,833,466 pounds of tea. In 1909 she only marketed abroad 199,792,400 pounds.

Tea culture in British India

There are about half a million acres of tea plantations in India, the greater part of which are in Eastern Bengal and Assam. In Ceylon, somewhat under four hundred thousand acres of land are planted with the tea shrub, and the value of the richly productive plantations has recently been further enhanced by interplanting them with rubber-trees. The average size of an estate is about three hundred acres; and though there has been a tendency of late years to group several plantations under one working staff, to reduce working and managing expenses, a large number of estates are of comparatively small size, and directed by British planters resident on the land.

Yet a good many planters are now only the servants of some company, instead of being, as they used often to be, the actual owners of the estates. An enormous labor supply of 400,000 coolies is necessary to run the Ceylon plantations. The Tamils of Southern India form the principal recruits. Entire families of men, women and children are collected in their villages and transported to Ceylon. The majority are fairly good workers, and return home with an amount of savings that often enable them to rise in life, but some are so pleased with the good wages they earn that they settle down permanently by the tea plantations.

In opening out a new tea garden, the coolies begin by clearing and hoeing and trenching a piece of the jungle. This forms a nursery. It is carefully fenced to prevent damage from cattle or wild animals, and planted with seed, which has been sprouted in seed-beds. Then it is covered with thatching to protect it from the scorching sun. In the meantime, the site of the future plantation is being cleared and hoed, and roads and drains are made through it. Stakes are then placed in the soil, about four feet apart, marking the rows in which the young tree plants are to be grown. The plants are taken from the nursery, when about a foot high, and very carefully planted in the lines of holes prepared for them. The planter has then to wait for three years for any return on the young plantation, and he has to bear a considerable running expense for the incessant labor needed to keep down the vigorous tropical weeds. He has to endure also the hot, stagnant, steaming heat of the jungle, which is so vital a necessity to the Indian tea plant that when Chinese methods of cultivating were first adopted the native shrub refused to grow properly.

How the tea leaves are classified

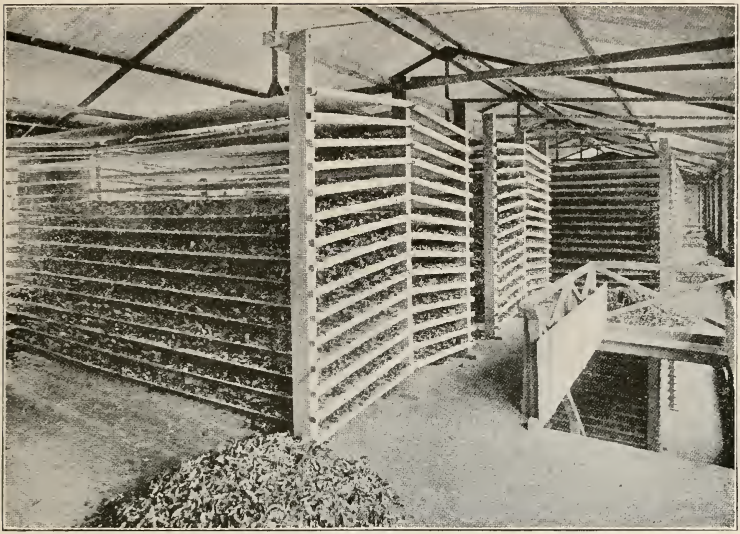
When grown in accordance with their native habit, the plants at the end of three years begin to send out an abundance of young leaf shoots, known as the "flush." The plucking is then carried out at regular intervals, and from time to time the bushes are pruned. This not only keeps the growth of the plant within bounds, and allows the plucking being done easily, but it promotes the growth of abundant flushes. In the colder climate of China and Japan, the flushing ceases in the winter. In Ceylon, however, it continues throughout the year, and the flush is ready for picking every ten or twelve days. Upon the size of the leaf when picked depends the quality of the tea. In fine plucking, the bud at the top of the shoot and the two young leaves just below it are taken. In medium plucking, three leaves are taken with the bud. In coarse plucking, four leaves and the bud are gathered.

The teas known as Pekoes are made from the fine plucking. Flowery Pekoe consists of the youngest leaf, Orange is made from the second leaf, and Pekoe from the third leaf. From the larger leaves Souchongs and Congous are prepared, and there is also a mixture of young and old leaves which is known as Pekoe-Souchong. In purchasing tea it is best to buy one of the Pekoes, because the quality of the beverage made from the youngest leaves is finer and more wholesome; and, besides, a less quantity of tea is needed in the teapot. All the money lavished on the advertisements of cheap, coarse teas made from large old leaves will not alter this fact.

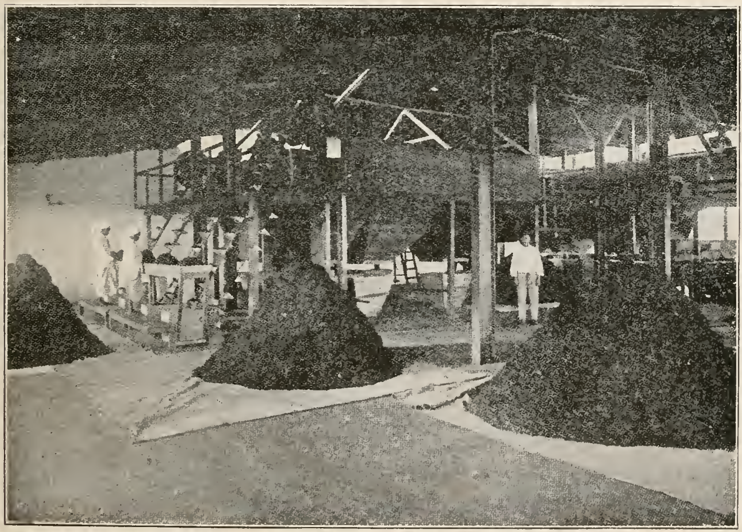
Curing tea by machinery

Gathered into baskets by women, and taken into the factory, the flush

THE PREPARATION OF TEA FOR THE MARKETS



TIERS OF TRAYS ON WHICH THE TEA LEAVES ARE TOUGHENED BY EXPOSURE TO THE AIR



MODERN MACHINERY EMPLOYED IN SORTING TEA is weighed, and then thinly spread out on shelves of canvas or wire mesh, placed one above the other, where the leaf naturally withers in good weather in about eighteen hours. The withered leaves are then shot into the rolling-machines, where they are bruised to allow their juices to become mixed, and they are also curled or twisted. From the rolling-machine the tea falls in yellow clinging masses into a roll breaker, that breaks up the masses and drops the tea into a sifter, where the coarser leaves are separated from the younger, finer growth.

Then comes the important process of fermentation. On its success largely depend the quality and character of the tea. As we have already explained, green tea that was formerly so popular is manufactured by omitting the fermentation process, but all black teas are fermented. This is accomplished by putting the rolled leaf in drawers or on mats, which are placed one above the other so as to permit the air freely to enter and work on the bruised leaves. During the fermentation the leaf emits a peculiar odor, and changes color; and when the right gradation of copper-brown tint has been attained—which usually takes about two hours—the leaf is fired in the drying-machines, and all other fermentation is arrested by the heat. Besides checking the fermentation, the firing process removes all the moisture without driving off the essential oil and other constituents that give a tea most of its value.

There are many types of firing-machines. But all of them act by sending a current of hot, dry air through the damp, fermented leaf, and making it dry and brittle. After being fired the tea is taken to the sorting room, and sifted by a machine through a series of moving sieves of varying sizes of mesh. The siftings are classed as Flowery Orange Pekoe, Orange Pekoe, and Pekoe No. 1. These are unbroken teas. But the coarser leaves, which do not shoot through the meshes, are transferred to breaking-machines, and broken up and passed through the sieves. They form the products known as Broken Orange Pekoe, Pekoe No. 2, and so on. The tea dust is shipped separately as "dust" and "fannings." The green teas are sifted in a similar manner into a descending scale of quality, represented by Young Hyson, Hyson No. 1, Hyson No. 2, Gunpowder, and Dust.

THE COFFEE PLANT AND COFFEE PRODUCTION

THE coffee trade of Great Britain is much inferior in importance to its tea trade. In Germany and America on the other hand, it is the national breakfast beverage, and so it is in Holland. The Arabian coffee plant is a shrub that grows to a height of about fifteen feet. It has been found wild in Abyssinia, and there are good grounds for supposing that this region of Africa was the natural home of the plant. The flowers are white in color and exquisitely fragrant, and from them is born the coffee cherry, which, as it ripens, turns from a dark green to a deep crimson. The outer portion of the fruit somewhat resembles that of an ordinary cherry, and inside the pulp are the two beans, of a greenish-gray tint, that form the coffee of commerce. Besides the Arabian coffee plant, there are about eighty known varieties of the shrub, but only two of them are cultivated in considerable quantity. One is found on the West Coast of Africa, and is called Liberian coffee. By reason of the fact that it is more resistant to disease, and

WHERE THE FRAGRANT COFFEE-BERRY IS GROWN

A cup of coffee begins its existence as a tiny shrub. When six months old it is transferred with others to the plantations and in three years grows to between six and ten feet high. It then bears fruit, and does so for about twenty years. The fruit is something like dark red cherries, but, instead of containing one stone, there are two seeds, or berries, of a light, green or yellow color. Here we see the coffee being picked.

more vigorous in growth than the Arabian coffee plant, it has gradually won for itself a place in the Orient.

The third variety of coffee plant is the Maragogipe, discovered in 1870 near the town of that name in Brazil. It is very hardy and twice as large as the Arabian plant, and its berries are double the size of the latter. It commands a very good price, and it is a special favorite in Germany, but our best judges are disinclined to allow that the quality of its infusion is in any way superior to that of the Mocha coffee berry. Experiments are still being made with the numerous other varieties in the hope of finding a kind especially fitted for cultivation in different regions.

How Brazil dominates the coffee market

The Brazilians now exercise over the coffee market a greater influence than even the British planter exercises over the tea market. They produce at least three-fourths of the beans, and with little or no effort their planters could flood the market. They refrain at present from so doing, in accordance with an agreement which was drawn up to prevent a continual over-supply from lowering the price of the produce. In the State of Sao Paulo, Brazil, where the most important plantations are established, the average yield is 1500 lbs. of berries from a thousand trees. But by clearing new land in the jungle and planting trees there the extraordinary return of 10,000 lbs. is obtained from the same number of trees. It is this immense reserve of productive force which enables Brazil to maintain her commanding position.

A hot, moist, tropical climate, with a high rainfall, and a rich, well-drained soil at a height of two thousand feet above sea level, is best for a coffee plantation. For though excellent coffee can be grown in dry regions, the crop is usually very small. In a moist climate, no nursery is used, for the seeds are planted directly in the fields, at a distance of from ten to fifteen feet apart. In Brazil, catch-crops of maize and beans are cultivated between the young shrubs. They not only yield a good return, but serve to shelter the coffee from the sun. In some countries, permanent shade-trees are often planted; this is not done in Brazil or Jamaica, but it is said to be absolutely necessary in Porto Rico.

Gathering the coffee crop

As a rule the coffee shrub first flowers in its third year, bearing then only a small crop. It is in the fifth year that the planter reaps the full fruit of his labor. A coffee estate in full flower is a very beautiful sight, but its glory quickly passes. The setting of the fruit occurs within twenty-four hours; then seven months and more are necessary to ripen it. The dark red cherries are stripped from the branches by hand in Brazil, but in Arabia they are allowed to fall off naturally on to a cloth spread beneath the tree. This ensures only quite ripe fruit being collected, and is no doubt one reason for the excellent qualities of Mocha coffee. The Arabians also keep to the old-fashioned method of spreading out the cherries on stone drying-grounds, and exposing them to strong sunlight. In two or three weeks the pulp dries, and is then removed by pounding the fruit in a mortar. In Brazil, the wet method of preparation is coming generally into use.

The cherries are put into pulping-machines, that consist of a thing like a huge nutmeg-grater revolving close to a curved metal plate. Between the grater and the plate there is no room for the cherries to pass, and they are ground to pulp. The mixture of pulp and seeds travels into a vat full of water that is kept agitated by machinery. The heavy seeds settle to the bottom, while the lighter pulp is removed by an overflow of water. The beans are drawn off by another stream of water into a large sieve, and from there they are taken to a fermentating vat.

They ferment for perhaps two days, until the pulpy layer that clings to the bean is removed. The beans are then sent into another vat, through which a shallow stream of water runs; and there they are trampled by the bare feet of the working people, and rinsed and raked by machinery until the parchment coverings are quite clean.

During this washing process the beans which have not developed properly rise up and float on the surface, and they are collected for making inferior coffee.

Removing the Parchment from the Bean

After washing, the beans are dried, either by sunlight or artificial heat, and then their silver parchment skin is peeled off by machinery. The machines are of various types, but the essential operation of all of them is to crack the parchment without damaging the bean.

The light pieces of skin are removed by a winnowing fan, and another rubbing and winnowing instrument gets rid of the silver skin, leaving the beans clean and in the condition of ordinary unroasted coffee.

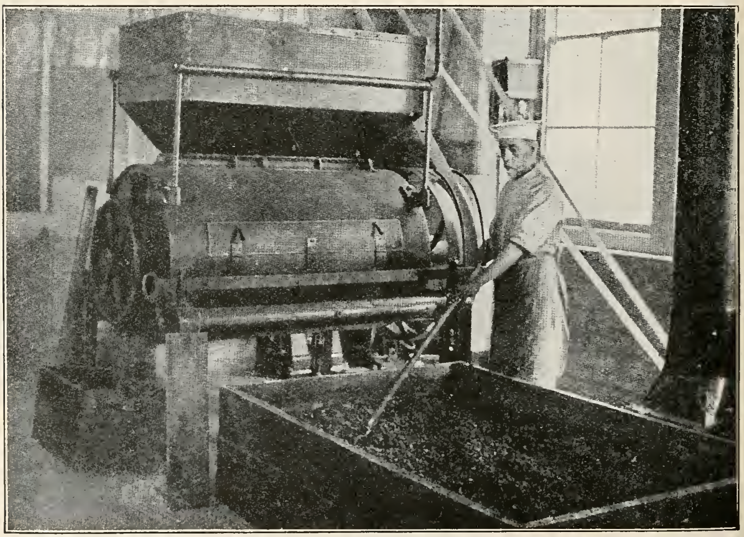
Some central American States, however, such as Costa Rica and Guatemala, and other countries with a tropical climate, send us their coffee with the skin on; this is known in the trade as parchment coffee. It is done partly to save the planters from the expense of erecting machinery, but mainly because freshly husked coffee is of a brighter and more attractive color than the other sort.

PRODUCTION AND USES OF COCOA AND CHOCOLATE

SEVERAL populous nations, and the Germans in particular, seem now to be becoming cocoa and chocolate drinkers instead of coffee drinkers. In the United States there has been an increase of 70 per cent in four years in the consumption of cocca products. In Germany for the same period, the increase was 61 per cent; in France, 21 per cent; in the United Kingdom, 11 per cent. No doubt much of this remarkably large and sudden increase is due to the growing popularity of the various kinds of chocolate sweet meats. But it must also be attributed in part to a growing taste for cocoa beverages at the expense of the morning cup of coffee that the Americans, Germans, and French used to prefer. The fact that the product of the cacao-tree is a food-drink as well as a stimulating beverage is no doubt partly responsible for its increasing popularity. But the main factor in the matter is, we think, the recent improvements which have variously been made in the machine processes of its manufacture.

Cocoa is naturally somewhat too fatty a beverage, and the ground kernels are also somewhat insoluble. So the modern manufacturer has been faced with the difficult task of reducing the fat of the kernels, and making the ground powder rapidly soluble in boiling water. Thus the manufacture of cocoa, in a fine and convenient form, has involved certain chemical and mechanical problems far more difficult of solution than the problems of tea and coffee manufacture. This is the reason of the long delay in the widespread popularity of

These are the cocoa-beans as they arrive at the factory in this country. They grow in large pods, looking like cucumbers, on trees in the West Indies, in the hottest parts of America, and in Africa. The pods, seen on the right, have to be opened, and the beans are taken out and dried. On the left of the picture we see the beans.



If we taste the cocoa-bean in its natural state it is far from palatable. So it is improved by a thorough roasting. This picture shows a man roasting the beans.

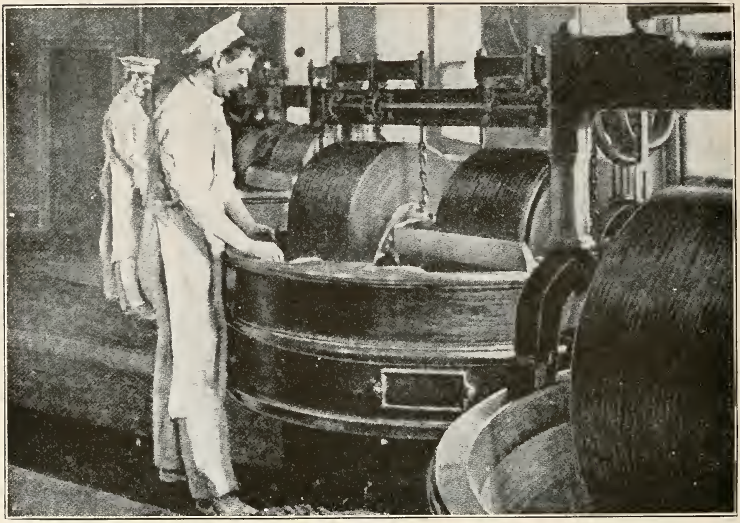
the "food of the gods," which Cortes, the conqueror of Mexico, introduced into Europe in 1528, when he returned to the Court of Spain. For many years the Spaniards closely guarded the secret of chocolate preparation, which they learned from the Mexicans, but in 1606 an Italian discovered the process of roasting the beans, and revealed it to the rest of Europe.

The French started to grow cocoa in Martinique in 1679, about the same time that the Spaniards began to cultivate it in the Philippine Islands. The British also took to planting cacao-trees in the West Indies and Guiana.

Laying out a cacao plantation

The cacao-tree sometimes grows to a height of forty feet, but in cultivation from fifteen to twenty-five feet are the usual limits of size of fully grown trees. There are many wild varieties, some of which are coming into cultivation. Yet the cacao-tree proper, which is a native of the tropical regions extending from Mexico to Brazil, still supplies the greater quantity of beans for cocoa and chocolate making. The small red flowers are curiously carried on the trunk or main branches. They are succeeded by pods of a cucumber shape, that turn from green to red as they ripen—a process which takes about four months. The trees are usually raised in nurseries, and planted out in warm, low-lying, sheltered plantations. It is best for the trees to be protected from the tropical sunlight, and the planters are finding a new and large source of profit in the use of rubber-trees as a shelter. When the trees are three or four years old they begin to flower; and after they have once produced fruit, regular crops may be obtained, with proper care, for fifty or more years. A cacao plantation is thus a valuable property; and where rich jungle soil is

The cocoa tree belongs to a family of trees called by a Greek name meaning "food for the gods." This picture is a very close view of the cocoa-pods growing out of the stem of a tree in a plantation in Ecuador, the chief country where this tree is grown. It needs a very hot climate, a deep, rich soil, and abundant moisture.



When roasted and broken up, the bean will make either cocoa to drink or chocolate to eat. Here chocolate is being made for famous shops, so the baked bean is ground in mills. The beans come out of these in the form of powder, and fine sugar is afterwards mixed with it to give the chocolate a pleasant taste.

Now we have the substance of the chocolate, but, as it is still a powder, it must be melted by great heat into liquid paste, so that girls can pour it into molds, which will make it, when cool, into pretty shapes.

available, a skilful planter, possessing an adequate supply of labor, can often make a large fortune in a few years.

Gathering and Roasting the Great Brown Beans

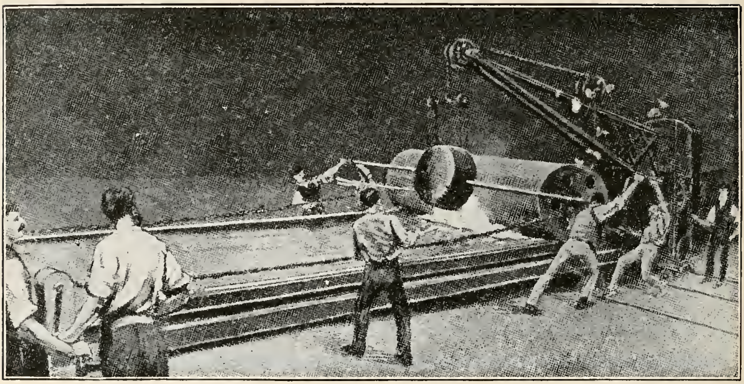
The ripe pods are gathered by means of a hand-knife, and the pods are then broken and the beans removed, and allowed to ferment in vats until they acquire a cinnamon-red color. It is in the process of fermentation that skill and experience are of vital importance. Certain microbes in the vats or fermenting sacks attack the embryo of the bean, and kill it; and then fermenting agents, known as enzymes, diffuse through the dead tissues, and alter the composition of the bean. The process lasts from nine to twelve days, and shrinks and toughens the skin, and alters the color and taste of the kernel. When the required color and aroma are obtained, the beans are stirred and scrubbed under running water, and made clean and smooth, and spread out on drying-floors, and dried either by sunlight, hot water, or steam-pipes. Then, packed in sacks, they are ready for the market.

After buying the beans in this state, however, some manufacturers submit them to further fermentation. This is done by soaking the beans in water for two days, and drying them off in a mild heat. The beans then usually pass through a sorting and cleaning machine, that rocks them through a series of sieves of varying mesh, and winnows away the dirt and hollow beans by means of a power-driven fan. It is necessary to sort the beans, so that the next process of roasting, which is an operation of great delicacy and far-reaching effect, may be perfectly performed. It does not do to roast a small bean with a large bean. For though they may be naturally of the same quality, they will differ very considerably after the same treatment. By arranging the beans according to size, the manufacturer is able to submit them to a varying roasting process that tends to keep them of even quality throughout. The roasting is done on a large scale by means of machines, through which hot air or gas is circulated with a forced draft. The roasting process, whether conducted over an open fire or in a machine, develops the aroma of the beans, changes their coloring matter, and renders their starch granules soluble.

After roasting, the beans are rapidly cooled down on a cooling-machine; and, while still slightly warm, they are passed between rollers that break the husks and collect and fan and clean the nibs. In adulterated cocoa or chocolate, however, some of the roasted husk is left to be ground up with the nibs. But honest manufacturers not only keep the nibs perfectly pure, but pass them through another machine, which extracts the hard, gritty germ which will impart a coarse flavor to the finished product.

Final Preparation for the Market

When free from their husk and germ, the nibs are milled or ground. In milling they are heated as they fall on the milling-stones; and by reason of their large percentage of fat they are reduced by the heat to a liquid state, and melted and ground together. The cacao flows out from the mill in a warm mass and then solidifies in pans. Thus are formed the blocks of raw cacao, which are ready to be mixed with sugar and flavoring matter for the manufacture of chocolate, or to be remelted and sent through a hydraulic press for the extraction of their fat. Some years ago it was a general practice to add a considerable amount of starch—obtained from potatoes, wheat, arrowroot—to the raw cacao. This was done to balance the natural amount of cocoa fat.



POURING MOLTEN METAL ON THE CASTING-TABLE IN A PLATE GLASS WORKS

MARVELS OF GLASS-MAKING

ONCE upon a time some Phœnician merchants beached their galley at the mouth of the river Belus, in Palestine, and prepared to cook their meal on the sands. Finding no stones on which to set their cooking-vessel above the fire, they brought some blocks of natron from the galley for this purpose. When the repast was over, and the fire was cold, they went to take up the blocks of natron, and found that these had melted in the fire, and combined with the fine river-sand to form a strange and wonderful transparent substance.

It was thus that the first and most important step in the art of glass-making was discovered by these adventurous merchants from Sidon. For the natron that they used to support their cooking-vessel was an impure form of carbonate of soda, and the fire, blown perhaps to a great intensity by the sea-wind, melted the soda and sand together and produced a glass-like material.

The Phœnicians were a very intelligent race; they experimented with the inferior glass they had discovered, and at last found that by adding a certain quantity of manganese they could produce a marvelous material of crystal clearness that could be made into a variety of objects.

Such, according to traditional researches in the matter, was the accidental origin of one of the most wonderful things of human manufacture. In the last twenty-five years so many marvels have been discovered that men have had their sense of wonder dulled by continual excitement. We can now create strange rays that can make many substances transparent to our vision, and we are so proud of these new wonders that we lose sight of equally marvelous things of every-day use that surround us. Yet the discovery of glass is just as extraordinary an achievement of human genius as the discovery of x-rays and radium. When men were able to manufacture in a large way a firm, solid material that was transparent to light, the destinies of the human race were altered. Mankind became possessed of faculties undreamed of by the most imaginative of wizards; for glass was an instrument of tremendous power, that enabled man to open the two gates of infinity—the infinity of the outer universe of space, the infinity of the inner universe of life.

HOW INDUSTRY GIVES EYES TO SCIENCE

Glass is the tool by means of which man controls light. It enables him to flood his dwelling-place with the cheerful and vital radiance of the sun, placing him beyond the chances of the weather, doubling his powers of work, and keeping down the germs of disease that undermine his health. It is glass that renews his faculty of vision when his eyesight grows dim. It is glass that enables him to construct a multitude of finer and more delicate senses, by which he penetrates to the bounds of the universe, dissolving a flaming star on the confines of space into its original elements, and by which he discovers the secret and invisible forms of life in the dust beneath his feet. And the wonderful pictures that print themselves upon the sensitive plate of a camera are obtained by means of lenses of glass.

Without the chance discovery of the process of glass-making, man could never have grown to his full stature. There would have been no hope of his ever obtaining a large control over the resources of nature, for it is simple truth that glass is the grand foundation of modern science.

THE TIME WHEN GLASS WAS WORTH ITS WEIGHT IN GOLD

For many centuries glass-making was mainly a fine art of an exquisite kind. Even when the Book of Job was written glass was worth its weight in gold; and the Phœnicians seem to have traded glass beads as jewels among the savages of Northern Europe. It used to be thought that the ancient Egyptians, at an early epoch, anticipated the discovery made by the merchants of Sidon, for a drawing of two workmen, apparently engaged in glass-making, has been discovered in a tomb of the eleventh dynasty. But the best authorities now agree that the drawing represents some other process of manufacture.

The Sidonians certainly held for a long time the monopoly in glass-making, and they spread the use of the new material throughout the Mediterranean. But gradually a knowledge of the secret of its manufacture extended to Italy, Spain, and Gaul, and the Romans especially became admirable artists in glass.

THE ROMAN CHEAPENING OF GLASS—FROM TABLE USE TO WINDOW USE

As a matter of fact, wealthy Romans used to pay extraordinary prices even for small glass vases of exquisite workmanship. They were esteemed above vessels of wrought gold. Table-glass of fine and elaborate shape was at first the principal glass industry of the Roman Empire, but mosaic work, made by combining bits of colored glass into a pictorial design, was soon developed in a variety of beautiful ways.

But the practical Romans at last found the cheaper process of making window-glass; and just as their empire was falling under the attacks of the Northern barbarians, the use of common glass for lighting purposes was extended. A small pane in a bronze frame may be seen at Pompeii, and fragments of window-glass have been picked up from the ruins of Roman villas in England. Glass of this kind was cast on a stone, and was usually very uneven and full of defects; and though it was capable of transmitting light, it must have allowed only an imperfect view of external objects. Very likely this defective method of manufacture was one of the causes why the builders of

ART GLASSWARE MADE DURING THE LAST 1500 YEARS

Rock crystal ewer, Italian, sixteenth century

Glass bowl with cover, Venetian, sixteenth century

Vase, Roman, fourth century

Wine glass, Venetian, sixteenth century.

Goblet, Venetian, sixteenth century

Examples of glassware made in the twentieth century at the Whitefriars Glass Works, London

SPECIMENS OF BEAUTIFUL WORK IN GLASS FROM A WIDE RANGE OF TIME AND PLACE

the early Christian churches adapted the lovelier mosaic work in colored glass for the purpose of lighting and beautifying their sacred buildings.

THE SECRETS OF GLASS-MAKING DEARER TO THE VENETIANS THAN LIFE

Alongside this general development of glass-making, there continued, chiefly in Venice, the more ancient traditions of the art of making exquisite table-glass and other vessels of use and beauty. Like the Sidonians, the glass-makers of Venice carefully guarded the secret processes by means of which they obtained a practical monopoly of fine glass-work. If any workman transported his craft into a foreign country, an emissary was sent by the State to assassinate him. Two men from Murano, the little island at Venice where the glass-makers still live, were induced by the Emperor Leopold of Belgium to migrate to his dominions, but they were killed by the order of the Council of Ten.

Any artisan caught attempting to go to foreign parts was sent to the galleys. In 1550 eight glass-makers from Murano were engaged by the English government to found a fine-glass manufactory at Crutchett Friars, in London. But they were so afraid of assassination by the emissaries of the Council of Ten that they tried to run away, and were imprisoned in the Tower, from which place they sent a petition for mercy to the Council. The Government of Venice tried to excuse their policy of maintaining the glass monopoly by murder, by alleging that the workmen who remained at Murano were thrown out of work for two and a half months a year by the spread of glass factories in Spain and Flanders. Undoubtedly, they frightened their migrating artisans sufficiently to conserve the Murano industry, and transmit its methods to us.

In the creation of the now famous Jena glass, was discovered the barium glass which combines the superb optical qualities of flint glass with the useful properties of ordinary crown glass. It would be necessary to go too far into the subject of lens construction to explain at length the possibilities opened up to the optician by the invention of the newer varieties of glass. But one of the consequences of the work of Schott and Abbé was that Germany became for awhile supreme in the manufacture of the best kinds of scientific instruments in which glass plays an important part.

The finest microscope objectives, the finest photographic lenses, and the best telescope glasses are all based upon the German invention of Jena glass. And though at the present time glasses of the newer types are produced in French and English manufactories in quantity and quality at least equal to the output of the Jena works themselves, these great optical achievements stand as a lasting monument of the pioneer work of Schott and Abbé.

As a matter of fact, these two remarkable men arrived at their discoveries by quite primitive methods. They merely tried everything likely to make a useful ingredient in a glass mixture, until they obtained the kind of transparency which they needed. They were compelled to use the ancient method of trial and error, or rule of thumb. For too little is yet known about the scientific aspects of glass-making to enable a more foreseeing process of research to be usefully employed. Men of science, indeed, are not yet agreed upon the fundamental problems of glass-making. Glass is still an unknown world, and its nature and its constitution have yet to be discovered. So it is regarded at present as a structureless solid, with the same lack of arrangement in the grouping of its molecules as is found in water.

It is a congealed liquid, in which the process of congealing involves no change of structure, but merely brings about a gradual stiffening of the liquid until it behaves like a solid. And the strange thing is that the ingredients out of which glass is made are not reduced to their liquid or molten state of combination simply by heat. It is the chemical dissolving action that they produce on each other which is the main factor. For instance, in ordinary process of glass-making, suitable proportions of sand, carbonate of lime, and carbonate of soda are mixed together by machinery, and shut into a vessel of fireclay enclosed in a gas furnace. The heat of the furnace first sets the mixture working. For by the mere action of the heat the carbonate of soda melts, and the carbonate of lime loses its carbonic acid, and is burned into caustic lime. Thus is produced a mass consisting of grains of sand and grains of decomposing carbonate of lime, all cemented together by the melted soda. By this time, however, the sand acquires a strong acid action; it attacks the carbonate of lime, and, moreover, does more than the heat of the furnace can by attacking and decomposing the carbonate of soda. The final result is the complete expulsion of all carbonic acid, and the formation of compounds of lime and sand and soda and sand, which remain in the finished glass in a condition partly of mutual chemical combination and partly of mutual solution.

Where salt-cake is used to make glass, neither the action of the heat nor the dissolving power of the sand is sufficient to bring about the rapid decomposition of the soda. So carbon has to be introduced in the form of coke or charcoal or anthracite coal, and this supply, assisted by the carbon already in the gases of the furnace, produces the desired effect.

THE ORIGINAL GLASS MADE BY NATURE IN VOLCANIC PROCESSES

It may not be generally known that one very curious kind of glass is sometimes manufactured by purely natural forces. This takes place in a volcanic eruption, in favorable circumstances, where the intense heat sets up chemical actions on various substances, that fuse together into an impure, semi-transparent glass known as obsidian. It varies in color from gray to black, and has been used in making works of art by the Egyptians, Romans, and Mexicans.

So what we do in a glass-furnace, after all, is merely to imitate some of the chance processes of volcanic action. But by selecting our materials, and using them in proportions that do not occur in Nature, we produce something that conduces in a remarkable degree to progress in knowledge and art, in health and comfort and luxury. The vitriable element in glass is practically always sand. The purest sand used only to be obtained from a deposit at Fontainebleau, near Paris, but an equally good material is now found at Lippe, in Germany.

THE CHEMICAL INGREDIENTS OF DIFFERENT KINDS OF GLASS

When the standard of quality is relaxed, a great number of sand deposits become available; and the manufacturers of each district rely on more or less local supplies. Finally, for the manufacture of the cheapest class of bottles, sands containing considerable traces of iron and other substances are often used. Flint glass used to be made by grinding flints to powder; and sandstone and certain other rocks are still sometimes treated in this manner. But crushing stone is an expensive and difficult process, and in practice only certain kinds of feldspar are widely used instead of sand. Their value is due to the fact that they not only contain the acid but also the alkali necessary in glass-making.

More usually, however, the alkali is obtained in a separate form from the acid of the sand. Various alkalies, such as carbonate of soda and sulphate of soda, are produced in the famous English alkali-works, which have almost a universal monopoly in the manufacture of these chemicals. The Germans, on the other hand, have a similar monopoly of the potash industry; and, having swept the old sea-weed burners out of existence, they supply most of the potash used in making potash glasses. Recently, however, millions of tons of potash have been discovered in the Mohave Desert in Arizona and California.

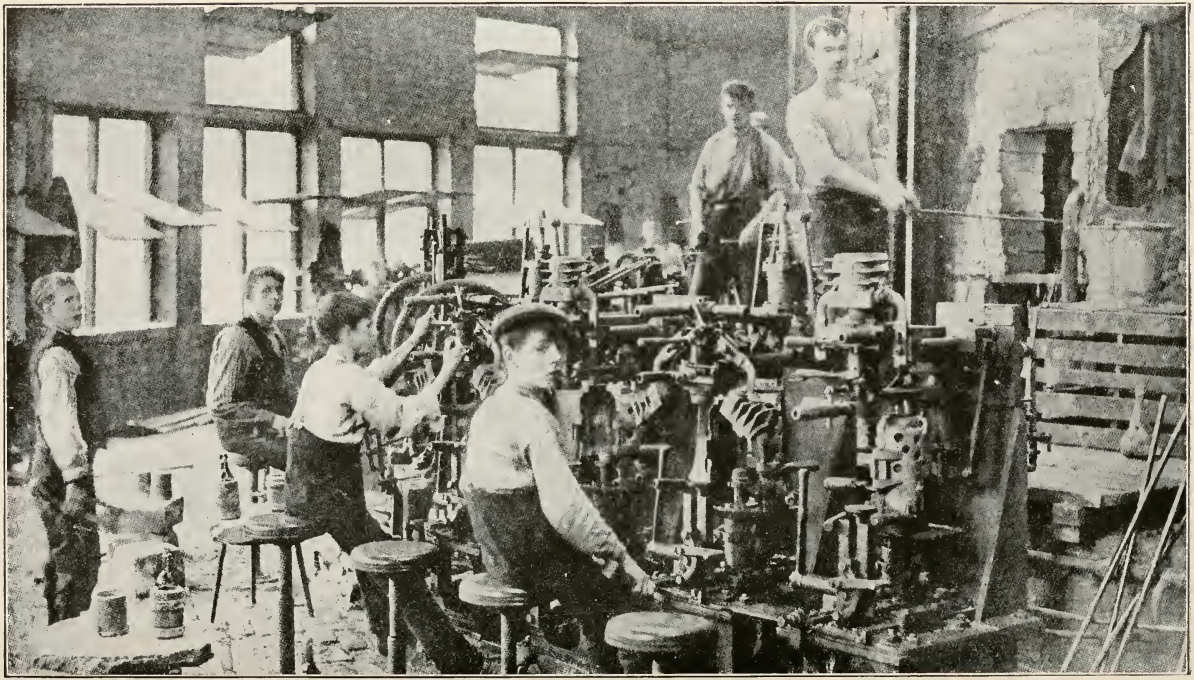
How primitive methods hold their own in the finest glass-work

In addition to the alkali basis of glass, there is a considerable number of other substances that are largely employed. For instance, lime is used for the production of all varieties of plate and sheet glass, as well as for bottles and certain kinds of pressed glass and blown glass. And, as we have already seen, the famous flint glass of England is based upon lead. In Jena glass, a preparation of the silver-like metal of barium is of importance, and zinc and magnesia and aluminum are used in the manufacture of special glasses for scientific purposes, where special properties are required. By using an electric furnace or an intense oxygen flame, quartz is now melted down into a valuable glass. Unlike ordinary kinds of glass, the fused quartz is transparent to the invisible ultra-violet rays of light, and it is largely coming into use for scientific purposes, and for the medical treatment of certain diseases.

In recent years the ancient craft of the glass blower has been transformed to a considerable extent into a factory process by the use of ingenious machines and metal molds into which the molten glass is driven by steam or compressed air. But in the production of the finest optical glass the method of manufacture remains strangely primitive. A single pot of fireclay is built into a furnace heated by coal or gas. When the pot is red-hot, the raw material is slowly shoveled in small quantities into its mouth, and it is ten hours after the last charge has been added that the furnace is driven to its highest temperature. It is kept at this temperature for twenty hours, and then the molten glass is stirred for another fifteen hours or more. This is done by means of a rod of fireclay, balanced on an iron beam above the furnace, with a wooden handle moved by a workman clad in an asbestos dress.

The heat is terrific, but the stirrer must not relax his efforts for a minute. The work is so trying and arduous that it has to be performed in short shifts. On it depends the ultimate success of the operation. The constant and prolonged stirring is necessary to remove from the glass the transparent threads and veins which are invariably found in ordinary glass. For the different ingredients have a tendency to separate, and rise or sink in the pot, according to their comparative lightness or weight. It is this process of separation that produces the common defects of glass, and it is only partly prevented by keeping the whole molten mass of the bath in a state of gentle but continual agitation. While the stirring goes on, the temperature of the furnace is allowed to diminish. The result is that the fluid gradually stiffens, until the fireclay rod can only be moved with great difficulty. The rod is then

MACHINERY SUPERSEDING HANDWORK IN MAKING MOLDS FOR GLASS BOTTLES



ONE MACHINE WORKS SEVERAL MOLDS AT ONE TIME BY COMPRESSED AIR, FINISHING COMPLETELY ALL THE PARTS OF A BOTTLE, READY FOR ANNEALING removed, and the furnace allowed to cool for another five hours.

The cooling is stopped, and the whole furnace is sealed up with brickwork and fireclay, and the glass is left to anneal gradually for one or two weeks. The pot is then drawn out, usually in a cracked condition, and is broken away by the aid of a hammer. In especially favorable circumstances, the whole of the glass may have cooled into a solid lump, but it is more usual to find it broken into fragments. These are picked over, and the pieces that are found to be absolutely clear are used in making the finest kind of lens.

THE MANUFACTURE OF GLASS BOTTLES

At the other extreme of the glass industry is a huge tank furnace, heated by producer gas, which turns out with punctual regularity the material from which bottles are shaped by machinery in millions every year. The tank is built of large blocks of fireclay, in the shape of an oblong basin, over which plays an intense flame of aerated gas. The raw materials are thrown into the furnace at the square end of the tank, and the gas flows uninterruptedly down the furnace to the colder semi-circular end of the tank that is pierced with working holes.

The workman thrusts an iron rod through one of these holes, and twirls around it a charge of the sticky fluid, which he drops into the machine. The liquid glass flows into a mold, from which it receives the shape of the neck of a bottle; and while it still retains its liquidity, a plunger makes a hole through it, and a stream of compressed air sweeps into this hole and blows the glass out, shaping the shoulder of the bottle. The glass is now growing decidedly stiff, and it passes into a finishing mold, where it is blown by powerful air pressure into its final shape, though in some cases another machine is needed to form the indentation at the base. By pressing a lever the workman then releases all the molds, thus leaving the bottle completely finished and entirely free. Two men and a boy work the whole machinery: one man gathers the glass from the tank, another works the levers that bring the molds into action, and the boy carries the finished bottles to a kiln where they are annealed by passing on trucks down a tunnel that is hot at one end and cold at the other.

HOW PLATE GLASS IS MADE

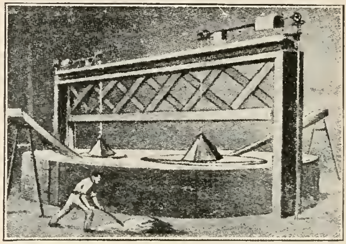
The tank furnace is also used for making plate glass. It is by no means uncommon for a single furnace to have a weekly output of a hundred and fifty tons of glass. The glass is withdrawn from the furnace by means of huge iron ladles, holding two hundred pounds of burning fluid, and carried by slings attached to trolleys running on an overhead rail. But a workman, covered in thick felt, with his face protected by a mask, in which there are eyeholes glazed with green glass, has to guide the ladle to the tank, and twist it into the fiercely hot molten glass. He then jerks off the threads and sheets of stiffening fluid that hang to it, and attaches the handle of the ladle to the overhead trolley. He next has to bear all his weight on the handle, to draw the whole ladle up from the molten bath in the furnace and out through the working hole in the tank. The operation only takes a few seconds to perform, but while it lasts the ladler is exposed to terrible heat, as an intense flame shoots through the working hole and curls up under the hood of the furnace.

Aided by a boy, the ladler then runs the charge of glass to an iron table, and there he empties out the molten liquid in front of a massive iron roller. Impelled by steam power, the roller passes over the glass, flattening it into a soft, red-hot sheet that has to remain on the iron table to cool and harden before it can be safely removed. The sheet is then taken on a stone slab into a long, low tunnel, hot at one end and cold at the other, and down this tunnel it very slowly passes, cooling and annealing, ready for cutting in the cutting-room.

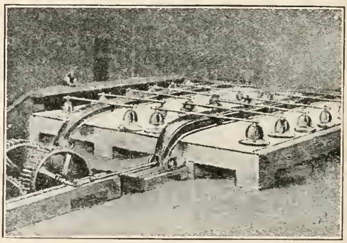
Making ordinary sheet glass

Ordinary sheet glass is also made in a tank furnace. Sometimes three independent furnaces are connected with each other by small openings through which the fused materials flow, refining as they flow. By this means a finer glass is produced, which has many of the properties of polished plate glass. The process of making sheet glass is very interesting. It is done by three groups of workmen — the pipe-warmers, the gatherers, and the blowers. The pipe-warmer heats a blowing-pipe, formed of an iron tube, about four and a half feet long, provided at one end with a wooden handle and a mouthpiece, and at the other end with a thick cone. After heating the pipe, the warmer blows through it, to see that the passage is clear, and then places the thick end in the tank of glass. Then the gatherer intervenes. With a knack born of long experience, he collects a quantity of glass round the butt-end of the pipe, by twisting it slowly in the molten fluid.

Cooling his first gathering, the gatherer dips the pipe in again and collects more glass, doing this with a skill that prevents any air-bubbles forming between the cool-glass and the fresh gathering. The pipe is then rotated across an iron trough filled with water. This helps to cool the pipe itself and stiffen the glass; and again the gatherer takes the pipe to the tank and collects more of the molten fluid. In some places the process is repeated five times; and the care and skill with which the operations of gathering are carried out largely determine the quality of the glass. Any want of regularity in the shape of the gatherings inevitably leads to variations of thickness in different parts of the sheet, while a careless gatherer introduces bubbles and other markings in the finished product. When the gatherings have been well done, the cooling glass forms a round mass, with the nose end of the pipe



Rough-grinding plate glass on a rotating table



Polishing plate glass with felt-covered disks

at its center. By means of special shaping instruments the glass is then molded into a sort of bottle, the neck of which fits over the nose of the blow-pipe.

Blowing out the sheet of glass

At this point the blower begins his work. He works on a stage, with some small furnaces, called blowing-holes, in front of him, or sometimes the stage is erected against the main melting furnace. It is simply a platform placed over a pit, called the blower's pit. The glass-maker first heats the bulb of glass in one of the blowing-holes, and then swings the pipe with a pendulum movement in the pit. Purely by its own weight, the half-remelted glass cylinder at the end of the pipe begins to elongate itself. Any tendency to collapse is checked by the blower blowing with his mouth through the pipe, which he also at times rotates. The operation of heating and lengthening the cylinder is repeated until the glass is equally distributed on all sides, forming a long tube, hanging by a thin neck from the blowpipe and closed at the lower end with a rounded dome. This rounded end is then opened by heating it till it is soft enough for a circle to be cut out with a pair of shears. Again the glass is heated, and hung downwards in the pit and twisted rapidly by the blower. The soft glass at the lower end immediately opens out under the whirling action, which the blower continues until the soft end straightens out in agreement with the rest of the glass tube.

When cooled and broken from the blow-pipe, the tube is split open by a hot iron or a diamond. It is then placed on a smooth slab in a hot kiln, where it grows soft enough to be flattened out on the slab by means of a wooden tool. Then, like other ordinary glasses, it is moved through a long tunnel, and annealed by being exposed to a change of temperature from hot to cold. It will be thus seen that the usual manufacture of sheet glass is a long, complicated, and laborious process, needing workmen of high skill. Various machines have recently been invented to do the work and cheapen the cost of the glass, but none of them is yet as perfect in achievement as are the hands of the gatherer and the blower.

In the finest kinds of sheet glass, the tank furnace is not used. The ingredients are put into pots, and a number of these are set in what is called a pot furnace, and exposed to the flame of aerated gas. The method is more costly than that of the tank furnace; the fuel consumption is greater, and the output smaller. On the other hand, the composition of glass can be more accurately calculated in a pot furnace than in a tank furnace, as the molten fluid is better protected from contamination by the furnace gases or dropping matter. It is also possible to melt thoroughly in pots materials which could not be made to combine in the open basin of a tank. In flint glass especially the molten material must be put in a closed pot, to protect it from the reducing action of the furnace gases.

Engraving a tumbler by means of a copper wheel and emery-powder.

How lamp chimneys and drinking glasses are made

All the best hollow glassware is in many ways costlier to manufacture than tank-fused glass. A good deal of hollow glassware, however, has been cheapened by means of machines in which molds are used. A lamp chimney, for instance, is made in the same

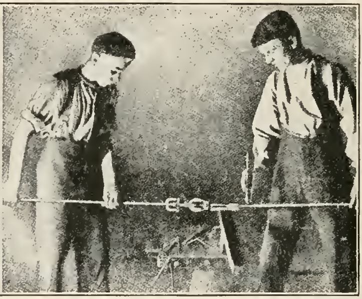
HOW A FRAGILE WINE GLASS IS SHAPED

The blower first collects some molten glass from the furnace on the end of his pipe.

By blowing through the pipe he forces the soft glass into the form of a big bubble.

He next molds the big bubble into the smooth bowl by rolling it on an iron table.

He then casts on sufficient molten metal to form the stem which he fashions with iron tools and afterwards adds the foot similarly.



The workman next marks a circle round the bowl with moistened iron pincers and breaks free the glass by a smart tap on his pipe.

The top of the glass is well heated in the furnace and is sheared to the required height.

The glass is now carefully removed from its holder and taken to the annealing oven where it is cooled very gradually to obviate brittleness way as the bottle, being blown in a mold with a flat bottom and a domed top, both of which are subsequently cut off. Molds are also employed in making electric light bulbs, and many of the cheaper kinds of tumblers and glasses.

Yet the old-fashioned glass-blower still produces the finest varieties of hollow glassware. At his best he is a craftsman of the old school, with a true feeling for the artistic qualities of his material. His implements are few and simple. He sits on a rough wooden bench, on which there are two projecting side-rails. On these rails he rolls his pipe, and close to him on the bench is a small rod and some shears and pincers, together with a flat board and a small slab of stone or metal. Gathering some melted glass on his pipe, he blows it into a small bulb, and lengthens the bulb by gently swinging it at the end of the pipe. Having obtained the shape he wants, he presses the bulb on the stone slab, and so gives it a flat bottom. He then breaks the bulb off the pipe by means of a hot wire, and sends the article to be annealed by gradual chilling. The rough edge is afterwards rounded off by the aid of a blowpipe flame, and a glass tumbler of perfect shape is ready for use.

Such is one of the simplest examples of the glass-blower's craft. For more artistic work he makes use of the pasty qualities of cooling glass. By raising or lowering the temperature of his material, he makes it now stiffer and now more fluid. He distends it by blowing, or he draws it out by swinging his pipe, and molds it with the aid of rods and tongs; or he holds it aloft and lets it fall in festoons under its own weight. With all these manipulations at his disposal, the glass-blower of the old school works the glass to his will, and fashions it into objects of great variety and beauty. Everything that he makes is original, having little of the regularity of size and shape of machine-made articles. For there is a natural variability in the curves and festoons made by the glass-blower, so that it is impossible for him, in his best work, ever to repeat himself.

In the machine work that now competes with the beautiful things made by the glass-blower, two different methods are used. In one, the glass is blown by compressed air into the various molds; in the other the material is pressed into shape by means of a mechanical plunger. The articles molded in these two ways, however, lack the fine fire-polish possessed by glass that is allowed to cool freely from the molten state. An attempt to produce a similar brilliance of surface on molded and pressed wares is often made by exposing them, in their


Polishing a large cut-glass bowl on a wooden wheel

finished form, to the heat of a furnace. This softens the surfaces and gives them a new brilliancy. But as the process cannot be carried out without softening the entire article, great skill is required to prevent serious deformation, and all sharp corners and angles tend to be melted and rounded off. Imitation cut glass is easily detected by the blunting effect of angles and corners produced during the reheating process.

Molded articles can also be distinguished by the slight projections caused by the pressed glass getting in the fine interstices between the various parts of the hinged molds. Probably it is in order to hide these defects that so much machine-made glass is over-decorated with grooves and spirals and ribbings.

Colored and stained glass

At present, the wonderful color resources of the glass-maker are, in a great many cases, hopelessly misapplied. But in the hands of a fine designer few other materials are capable of yielding results equal in beauty to that of colored glass. Many of the coloring agents are cheap, as only a minute quantity is needed to produce lovely, delicate, and jewel-like tints. Indeed, the sole difficulty involved in the use of several important coloring substances is that so little of them is needed that it is hard to weigh exactly the amount that is required. The range of colors is practically unlimited, particularly as the coloring elements can be employed in almost any combination to produce exquisitely graduated tints. Even stained glass-work of the finest quality is no longer a lost art. Modern craftsmen have at their disposal materials quite as excellent as those employed in the thirteenth century.

The jewel-like splendor of the best ancient glass was for many years unattainable, owing to a curious cause. Modern glass was too good for the purpose. It was so transparent that the light passed through it, instead of bringing out the interest and mystery of the glass itself. It was found that the ancient stained glass was very badly made, with an irregular surface and an extraordinary number of internal defects—airbells, veins and even bits of foreign matter. But these things scattered and twisted and reflected back the light, until the rays appeared to emanate from the body of the glass itself, which thus seemed to shine with an internal light of its own. So, by having his glass made very badly, the modern worker in stained glass has been able to equal the lovely effects of the ancient masters of his craft.

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