THE SCIENCES

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A READING BOOK FOR CHILDREN

ASTRONOMY · PHYSICS · HEAT · LIGHT · SOUND
ELECTRICITY · MAGNETISM · CHEMISTRY
PHYSIOGRAPHY · METEOROLOGY

BY

EDWARD S. HOLDEN

YESTERDAY'S CLASSICS
CHAPEL HILL, NORTH CAROLINA

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TO

MY YOUNG FRIEND

Mildred Greble

PREFACE

The object of the present volume is to present chapters to be read in school or at home that shall materially widen the outlook of American school children in the domain of science, and of the applications of science to the arts and to daily life. It is in no sense a text-book, although the fundamental principles underlying the sciences treated are here laid down. Its main object is to help the child to understand the material world about him.

All natural phenomena are orderly; they are governed by law; they are not magical. They are comprehended by some one; why not by the child himself? It is not possible to explain every detail of a locomotive to a young pupil, but it is perfectly practicable to explain its principles so that this machine, like others, becomes a mere special case of certain well-understood general laws.

The general plan of the book is to waken the imagination; to convey useful knowledge; to open the doors towards wisdom. Its special aim is to stimulate observation and to excite a living and lasting interest in the world that lies about us. The sciences of astronomy, physics, chemistry, meteorology, and physiography are treated as fully and as deeply as the conditions permit; and the lessons that they teach are enforced by examples taken from familiar and important things. In astronomy, for example, emphasis is laid upon phenomena that the child himself can observe, and he is instructed how to go about it. The rising and setting of the stars, the phases of the moon, the uses of the telescope, are explained in simple words. The mystery of these and other matters is not magical, as the child first supposes. It is to deeper mysteries that his attention is here directed. Mere phenomena are treated as special cases of very general laws. The same process is followed in the exposition of the other sciences.

Familiar phenomena, like those of steam, of shadow, of reflected light, or musical instruments, of echoes, etc., are referred to their fundamental causes. Whenever it is desirable, simple experiments are described and fully illustrated, and all such experiments can very well be repeated in the schoolroom.

Finally, the book has been thrown into the form of a conversation between children. It is hoped that this has been accomplished without the pedantry of *Sandford and Merton* (although it must be frankly confessed that the principal interlocutor has his knowledge very well in hand for an undergraduate in vacation time) or the sentimentality of other modern books which need not be named here. The volume is the result of a sincere belief that much can be done to aid young children to comprehend the material world in which they live and of a desire to have a part in a work so very well worth doing.

EDWARD S. HOLDEN

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INTRODUCTORY CHAPTER

(To be read by the children who own this book)

Let me tell you how this book came to be written. Once upon a time, not so very long ago, a lot of children were spending the summer together in the country. Tom and Agnes were brother and sister and were together all the day long; bicycling or playing golf in the morning, reading or studying in the afternoon. The people who lived in the village used to call them the *inseparables* because they were always seen together during their whole vacation from June to September.

Their cousins Fred and Mary always spent a part of every summer with them; and when they came there were four inseparables, not two. The children liked the same games, liked to read the same books, to talk about the same kind of things, and so they got on very well together; though sometimes the two boys would go off by themselves for a hard day's tramp in the hills, or to shoot woodchucks, or for a very long bicycle ride, leaving their sisters at home to play in the garden with dolls, or to do fancywork and embroidery, or to play tennis, or to read a book together. Tom was thirteen years old then, and his sister Agnes was nine; cousin Fred was ten and his sister Mary was twelve.

When the summer afternoons began to get very warm, in July, a rule was made that the children should spend them in the house, or on the wide, shady porch, or else under the trees on the lawn, or in the garden. Golf, tennis, and wheeling had to be done in the morning; the afternoons were to be spent in something different. Tom's father used to say that the proverb

All work and no play
Makes Jack a dull boy

was only half a proverb. It was just as true, he said, that

All play and no work
Makes Jack a sad shirk.

And so a part of every summer afternoon was given up to reading some good book, or to study, or to work of some sort. The two boys had their guns and wheels to keep thoroughly bright and clean, and a dozen other things of the sort; the two girls had sewing to do; and all of them together agreed to keep the pretty garden free from weeds.

Almost any afternoon you might see the four inseparables tucked away in a corner of the broad piazza, each one busy about something, and all talking and laughing—except, of course, when one of them was reading, and the others paying good attention. Tom's big brother Jack was at home from college, and in the afternoons he was almost always on the porch reading, or else on the green lawn lying under the trees; and Tom's older sisters, Mabel and Eleanor, were there too, sewing, or embroidering, or reading, or talking together.

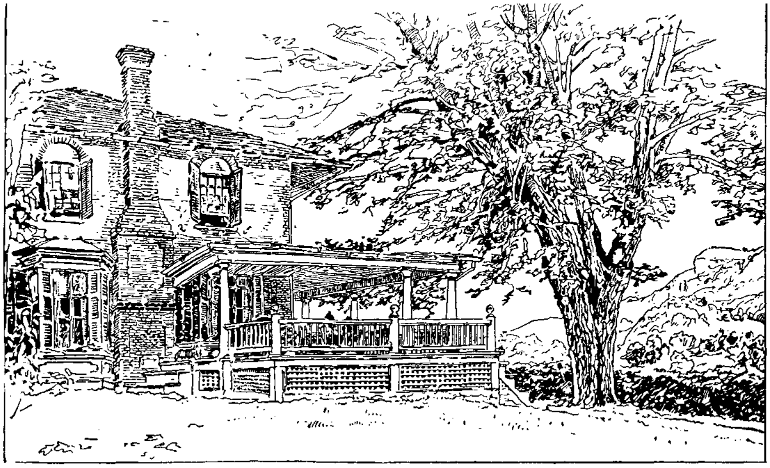

FIGURE 1 THE PORCH

So there were two groups, the four children—the inseparables—and the three older ones. When the children came to something in their book that they did not quite understand, Tom would call out to his big brother Jack to explain it to them, and Jack would usually get up and come over to where the children were and tell them what they wanted to know. Almost every day there were conversations of the sort, and explanations by some one of the older ones to the four children. All kinds of questions would come up, like these:

"Jack, tell us why a 'possum pretends to be dead when he is only frightened and wants to get away."

"Jack, tell us why a rifle shoots so much straighter than a shot-gun or a musket."

"Jack, what's the reason that a lobster hasn't red blood?" or else:

"Eleanor, what is the difference between a fern and a tree?"

"Is that coral bead made by an animal or an insect?"

"What is amber, anyway?" and so on.

The children had no end of questions to ask, and Jack or one of the older girls could generally answer them. When they could not give a complete answer the dictionary was brought out; and if that was not enough, a volume of the encyclopædia. Sometimes the questions were talked over at the dinner table and the whole family had something to say. Tom's father had traveled a great deal and could almost always tell the children some real "true" story—something that had happened to himself personally, or that he had read.

The chapters in this book are conversations that the children had among themselves or with older people. They are written down here in fewer words than those actually spoken, but the meaning is the same.

When the children were talking about electric bells, for instance, they actually strung a wire from one end of the long porch to the other, and put a real bell at one end of it and a push button and a battery at the other. In this book there is a picture showing exactly what they did; but, after all, you cannot understand an electric bell half so well by a picture as you can by the real bell and the real wire.[1] So when one of the children who is reading

[1] Children should be careful to read the titles printed under each picture with attention. The titles explain what the picture means.

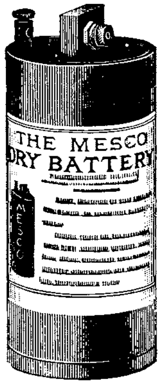

FIGURE 2 A CELL OF DRY BATTERY

The two wires are to be fastened to the two screw posts in the picture—one at the left-hand side, and one in the middle, of the top of the cell.

this book comes to an experiment he must read all that the book says about it, and understand it as well as he can. If he can get an electric battery, and a bell, and wire, and a push button, then the picture in this book will tell him exactly how to join them together; and when he has done this and actually tried the experiment—and made it succeed—he will know as much about electric bells as he needs to know.

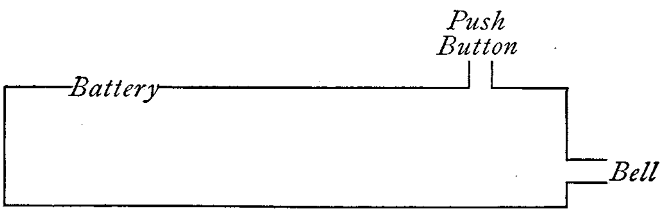

FIGURE 3

If he cannot get the bell and the wire, and so forth, he can probably see a bell of the sort somewhere; and if he keeps his eyes open and thinks about what he has read, he can certainly understand how it works. Here is the battery always trying to send out a stream of electricity along any wires joined to the two screws at the top. Here is the wire, which is almost a complete loop—almost but not quite. If the loop were continuous,—if the wire were all in one piece,—then the stream of electricity would flow along the wire from the battery and would ring the bell.

The use of the push button is to make the wire continuous—to join the two ends of it so that the stream of electricity can pass along it. When you have done this—when you have joined the ends of the loop of wire—the bell rings, and only then, which is just as it should be.

This book gives the pictures and the explanations. They can be understood by paying attention; and when they are once understood a great number of things will be clear that all children ought to know, and that have to be learned sometime. Why not now? The sooner the better.

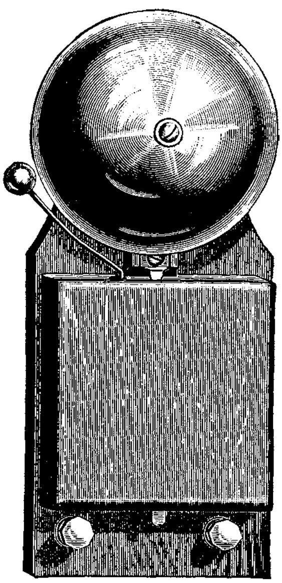

Figure 4 An Electric Bell

The wires are fastened to the two screws at the bottom of the box.

If you read what is written in the book and perfectly understand it, that is very well. If there is an experiment to be tried, and you can get the things to try it with, so much the better. If you have any trouble in understanding, ask some one—your father, your mother, your teacher—to explain to you. If you can find another book—a dictionary or an encyclopædia—that describes the same experiment, read that too. Perhaps it will tell you what you want to know, better, or more simply, or more fully, or in a different way. Then, finally, keep your eyes open to actually see in the world the things that are talked about in this book. When you see them try to understand them. Remember what you have read here, and you will find that you understand a good many things that you see about you every day. Somebody understands these things,—push buttons, electric lamps, telescopes, and so forth. Why should not you? You can if you pay attention enough. The world is, after all, your world. It belongs to you as much as it belongs to any one. The things in it can all be explained and understood. It is everybody's business to *try* to understand them at any rate. All these things concern you. The more you know about them, the better citizen you can be—the more useful to your country, to your friends, and to yourself.

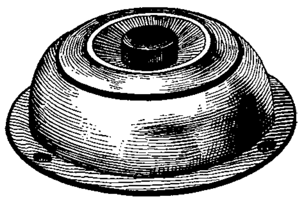

Figure 5 A Push Button

The two wires are fastened to two screws inside the push button.

THE MOON

The moon from a photograph taken with the great telescope of the Lick Observatory.

ASTRONOMY

THE SCIENCE OF THE SUN, MOON, AND STARS

The Earth as a Planet.—The children were looking at a map of the world one fine afternoon and studying the way the land and water are distributed, when Agnes said: "I never knew before how little land there was on the earth. Why, there is *very* much more water than land." "Oh, yes," said Tom, "there's very much more water on the surface; but it's all land at the bottom of the ocean. The sea is about three miles deep, you know, and then you come to the ocean bottom, and that is solid land again. The earth is nearly all rocks and soil; only a little of it is water, after all, but that little is on the surface, of course, and that is why it shows."

Agnes. So the earth is almost all land; if you dig down deep enough, you should come to rocks, even below the oceans?

Tom. Yes, and if you went up high enough, you would come to nothing. You would come to air first, and then by and by to no air, and then you would come to just nothing—to empty space.

Agnes. Well, it isn't quite empty, as you call it. There are other globes in space. There are other planets, and

Figure 6. America

Figure 7. The Old World

the sun and the moon, and there are simply thousands of stars. So space isn't empty; it is pretty full!

Distance of the Moon and of the Sun from the Earth.—Here Tom's big brother Jack looked up from his book and said: "Well, that depends on what you call full. It is 240,000 miles from here to the moon, and the moon is the very nearest of all the heavenly bodies to us. There is a good deal of empty space between us and the moon, it seems to me."

Agnes. Two hundred and forty thousand miles! Oh, Jack, is that right?

Jack. Why, that isn't a beginning; how far off do you suppose the sun is? It is 93,000,000 miles—millions this time, not thousands; and some of the planets are much farther off yet, and every one of the stars is farther off still.

Agnes. Jack, tell us about it, will you? We don't know, and you do.

Jack. The very first thing you have to think about is the size of the earth. How far is it through and through the earth, Tom? If you pushed a stick through the earth from New York to China, how long would the stick be?

The Diameter of the Earth.—*Tom*. The geography says that the diameter of the earth is 8000 miles; so the stick would have to be 8000 miles long,—as long as from Cape Horn to Hudson Bay, my teacher says.

Jack. That's about right. Suppose there were a

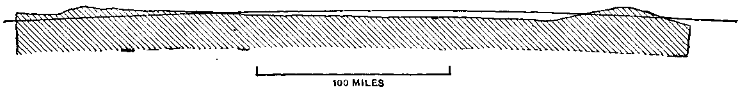

Figure 8

This picture shows the height of land on the earth compared to the depth of the sea. If you could cut the earth through and through with a knife and look at one part only, it would look something like the picture. All the shaded part is land. The curved line drawn all across the picture, near the top, is the curve of the surface of the oceans. Part of one of the oceans is shown by the white space below this curved line and above the floor of the ocean itself,—the shaded land. The curve of the ocean surface is continued across the picture underneath the mountains. If the surface of the earth were all water, the bounding line would be this curve. From side to side of the picture is about 350 miles. If the whole circle of the earth were drawn, it would be about eight feet in diameter. That is the scale of the drawing.

railway from Hudson Bay to Cape Horn, and express trains running on it at the rate of 40 miles an hour. Let us see how long they would take to go the 8000 miles. They would go 40 miles in one hour, and 80 miles in two hours, and 960 miles in a day—say 1000 miles a day. Well, they would take eight days to go the 8000 miles, then. Now, suppose we could build a railway to the moon. How long would an express train take to go the distance? Take your pencil, Tom, and cipher it out.

Tom. You said the distance from the earth to the moon was 240,000 miles. If the train goes 1000 miles a day, it would take 240 days. I don't need any pencil.

Jack. Sure enough; and 240 days is eight months (8 x 30 = 240). It would take the train eight months to go from the earth to the moon, then—eight whole months, traveling night and day at forty miles and more every hour.

Agnes. I should be nearly a year older when I got there than when I started, then.

Jack. Yes, and recollect that there are no stations on the railway to the moon. The moon is the heavenly

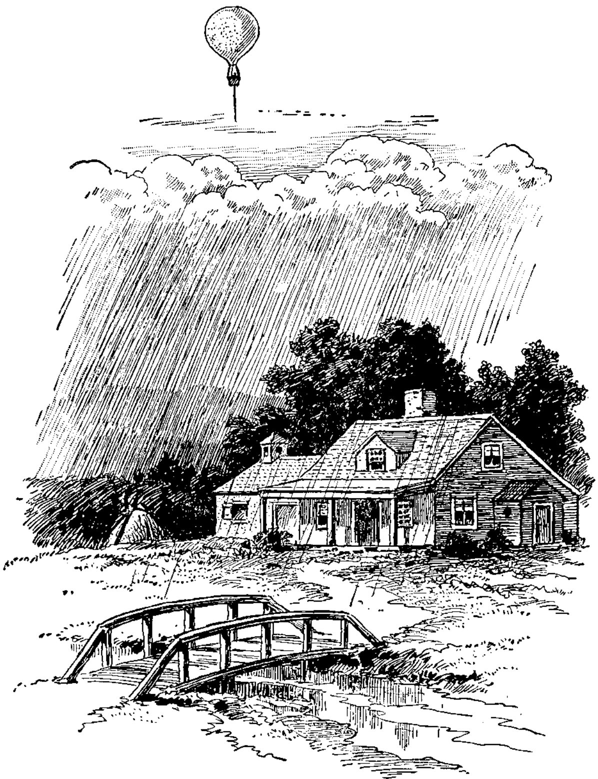

Figure 9 A Balloon

Balloons carrying men have gone up more than five miles, and small balloons carrying thermometers, etc., have been sent nearly ten miles high. The atmosphere of the earth extends upwards a hundred miles or so, but beyond this there is no air—nothing but empty space.

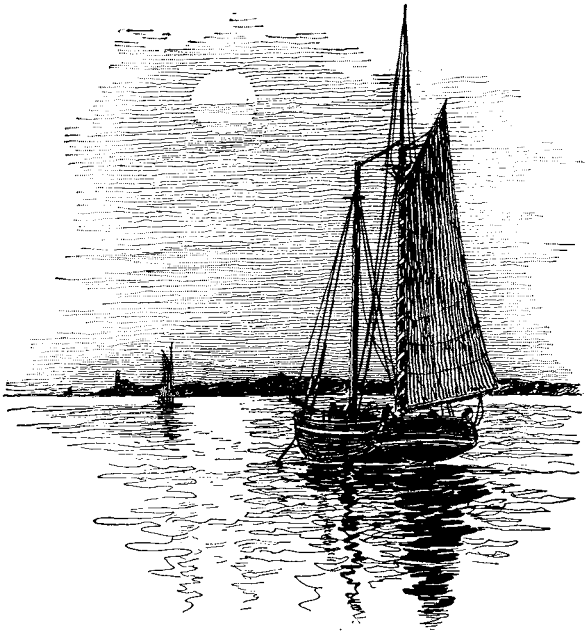

FIGURE 10 THE FULL MOON RISING IN THE EAST

body that is nearest to us, so that space is pretty nearly empty, after all.

Distance of the Sun from the Earth.—*Tom.* How far did you say it was from the earth to the sun—93,000,000 miles?

Jack. That's right. You will need your pencil to figure out how long the express train would take to go from the earth to the sun, Tom.

Tom. Yes, it is like this, isn't it? The train goes 1000 miles in a day; then it will take 93,000 days to get to get to the sun.

30 x 93000	days
12 x 3100	months
258 1/2	years

It would take 3100 months, that is more than 258 years, to get to the sun. That's a long journey! You would have 258 birthdays on the road, Agnes.

Jack. Put it this way, Tom: You all know that the Pilgrims landed at Plymouth Rock in 1620. Suppose that one of those Pilgrims, directly after he had landed from the ship, decided to take a train to the sun. He would have had to travel until the year 1878 (1620 + 258 = 1878); that is, if he had lived to make the journey. Even the wild elephant, which is thought to live at the most 150 years, would not survive a journey of 258 years.

Tom. Two hundred and fifty-eight years!

Figure 11 The Pilgrims landing on Plymouth Rock from their Ship, the "Mayflower," Dec. 20, 1620

The Planets Mercury and Venus.—*Jack.* Yes, and nearly all that space is empty too. There are only two planets between the earth and the sun—Mercury and Venus.

Agnes. Venus, the evening star?

Jack. Yes, Venus is the evening star sometimes. Venus and Mercury are the only planets that the Pilgrim would pass on the road from earth to the sun. Space is rather empty, isn't it?

Agnes. Aren't there any stars in between the earth and the sun, Jack?

Jack. Not one; the real stars are thousands and thousands of times farther off. We call Venus the "evening star," but Venus is not a star at all, but a planet. Let me tell you, so that you can make a sort of picture of it all in your minds. The sun is there in the middle of space and all the planets move around him, just as the earth does. Nearest to the sun is the planet Mercury, and then comes the planet Venus, and then the planet Earth.

Agnes. That sounds queerly— "the planet Earth"— though of course we know the Earth *is* a planet.

The Planets Mars, Jupiter, Saturn, Uranus,[1] and Neptune.—*Jack.* Yes, exactly so. And then there are other planets farther away from the sun than the earth; Mars for one, and then Jupiter, and then Saturn, and then Uranus, and then Neptune. That is all we know

[1] Pronounced ū′ra-nus.

of; there may be more of them. Neptune is thirty times as far from the sun as the earth is. Here is a little table that I will write down for you to keep. You need not memorize it, only recollect that Mercury and Venus are nearer to the sun than we are, and that all the others are farther away.

Distances of the Planets from the Sun

The planet *Mercury* is 36 million miles from the sun
The planet *Venus* is 67 million miles from the sun
The planet *Earth* is 93 million miles from the sun
The planet *Mars* is 141 million miles from the sun
The planet *Jupiter* is 483 million miles from the sun
The planet *Saturn* is 886 million miles from the sun
The planet *Uranus* is 1782 million miles from the sun
The planet *Neptune* is 2791 million miles from the sun

Jupiter is five times, and Neptune is thirty times, as far from the sun as the earth is.

Tom. Isn't there a map of all these planets that we can see?

Jack. No, and there's a good reason why. Suppose you tried to make a map of them, and suppose you took the distance from the sun to the Earth on the map to be an inch. Don't you see that the distance from the Sun to Neptune would have to be thirty times one inch, and the page of your book thirty inches wide—nearly a yard wide?

Tom. Of course, no book has a page as big as that; but you might make little maps.

How to Make a Map that Shows the Sun and Planets.—*Jack*. You and Agnes can make a map yourselves to-morrow morning, if you want to, when you go out for a walk, and I'll tell you how to do it.

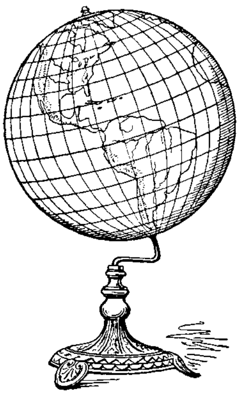

Figure 12 A School Globe

Suppose you take the large globe in the library, that you were looking at just now, to stand for the Sun. It is two feet in diameter. Well, the diameter of the real sun is 870,000 miles, and your map has to be made all to one scale. Every step of yours is about two feet long, isn't it, Tom? Try it.

Tom. Yes, my steps are almost exactly two feet long.

Jack. Well, remember to-morrow that every step you take along the road to the village is really two feet long, but that it stands on the map for 870,000 miles.

Agnes. Are we going to make the map along the road?

Jack. My dear, you have to do it that way; your map is going to be nearly a mile and a quarter long. You have to use the whole country round to make it.

Agnes. Well, that *is* a map!

Tom. How shall we make it, Jack?

Jack. You start, you know, with this globe in the house to stand for the Sun. The globe is two feet in diameter, and the real Sun is 870,000 miles in diameter.

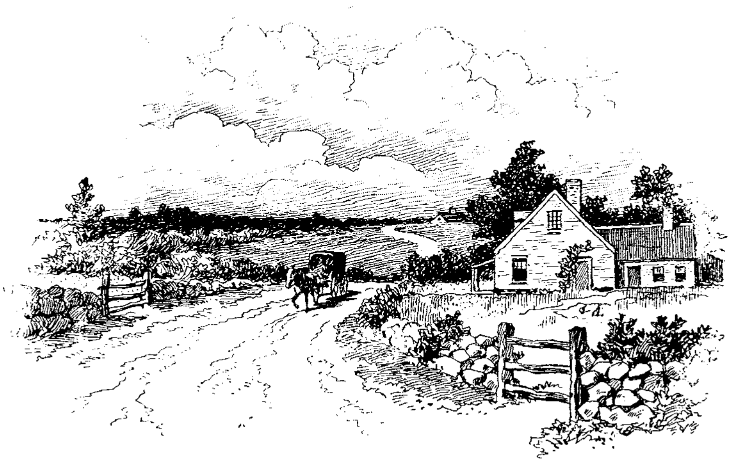

FIGURE 13 THE ROAD TO THE VILLAGE

Scale of the Map.—"So, recollect, every two feet on your map is 870,000 miles. Every one of your steps, Tom, stands for 870,000 miles.

"You must take with you

- a very small grain of canary-bird seed to stand for the planet *Mercury;*
- a very small green pea to stand for the planet *Venus;*
- a common green pea to stand for the planet *Earth;*
- a rather large pin out of Agnes' work box, and let its round head stand for the planet *Mars;*
- an orange to stand for the planet *Jupiter;*
- a golf ball to stand for the planet *Saturn;*
- a common marble to stand for the planet *Uranus;*
- a rather large marble to stand for the planet *Neptune.*

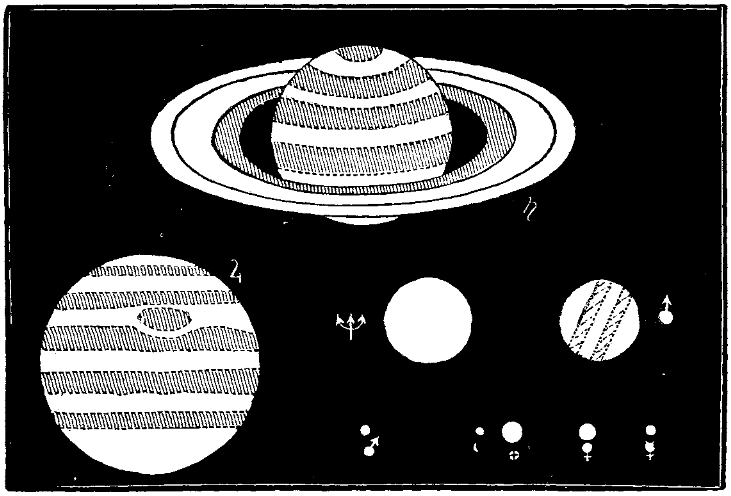

FIGURE 14

The sizes of the planets of the solar system (the sun's family) compared with each other.

♄ = Saturn; ♃ = Jupiter; ♆ = Neptune; ⛢ = Uranus; ♂ = Mars; ☾ = our Moon; ⊕ = Earth; ♀ = Venus; ☿ = Mercury.

Sizes of the Planets Compared to the Sun.—"If this globe, two feet in diameter, stands for the Sun (which is really 870,000 miles in diameter), then a common green pea is just the right size to stand for the Earth (which is really 8000 miles in diameter) and an orange is just the right size to stand for Jupiter, and so on. You are going to carry all the planets off in your pocket, and when you have put them down in the right places you have made your map."

Tom. How shall we know where to put them down?

Jack. I will give you the right number of steps to take between the Sun and every one of the planets. If one of Tom's steps is 870,000 miles, then:

Mercury (the canary seed) is
41 steps from the Sun (the globe at the house)
Venus (the small pea) is
77 steps from the globe that stands for the Sun
Earth (the pea) is
107 steps from the globe that stands for the Sun
Mars (the pin's head) is
162 steps from the globe that stands for the Sun
Jupiter (the orange) is
555 steps from the globe that stands for the Sun
Saturn (the golf ball) is
1019 steps from the globe that stands for the Sun
Uranus (the small marble) is
2048 steps from the globe that stands for the Sun
Neptune (the large marble) is
3208 steps from the globe that stands for the Sun.

Those are the right distances, and you can make your map tomorrow morning when you go for a walk. Recollect that the globe in the house stands for the Sun. You are to walk away from it along the road to the village until you've take 41 steps. Stop there and put down the canary seed to stand for the planet Mercury. Then go on 36 steps more and you will be 77 steps from the model of the Sun. This will be the place to put the small green pea that stands for the planet Venus; then go on 30 steps more and you will be 107 steps away from the Sun. This will be the place to put down the green pea that stands for the Earth, and so on. The last planet—Neptune—will be 3208 steps away from the house,—about one and a fifth miles away.

Agnes. I don't believe we can count such large numbers, Jack; we shall be sure to forget them and lose the count.

Jack. True enough, Agnes. Let me see if I can't make it simpler for you. I will write down on a card all that you have to remember, and we can make the numbers that you have to count smaller. We can do it this way; instead of counting the distances from the Sun to each planet, we will count the number of steps between each planet and the next one: this way. Here is the card that Jack wrote:

If one of Tom's steps is 870,000 miles, then:

The distance from the model of the Sun to the canary seed that stands for the planet Mercury is 41 steps; the distance from Mercury to Venus is 36 steps farther; the distance from Venus to the Earth is 30 steps farther; the distance from the Earth to Mars is 55 steps farther; the distance from Mars to Jupiter is 393 steps farther; the distance from Jupiter to Saturn is 464 steps farther; the distance from Saturn to Uranus is 1029 steps farther; the distance from Uranus to Neptune is 1160 steps farther.

Note.—The numbers that are needed to make the map are obtained in this way: If one step is 870,000 miles, then

Distance from the Sun to	**Miles**	**Steps**	**Differences**
Mercury	36,000,000	41	—
Venus	67,200,000	77	36

Earth	92,900,000	107	30
Mars	141,000,000	162	55
Jupiter	483,000,000	555	393
Saturn	886,000,000	1019	464
Uranus	1,782,000,000	2048	1029
Neptune	2,791,000,000	3208	1160

In the last column are the differences between the numbers just preceding: 77 less 41 is 36, 107 less 77 is 30, 162 less 107 is 55, and so on. If the model of the planet Mercury must be 41 steps from the model of the Sun, and if the model of the planet Venus must be 77 steps from the Sun, then the model of Venus must be 30 steps away from the model of Mercury, and so on for the others.

When the next day came, Tom and Agnes set out to make the map of the Sun and all the planets. The school globe in the house stood for the Sun, and they carried the models of the planets with them, as well as the card that showed how far apart the planets were to be on the scale of their map. Agnes kept the card in her hand and told Tom how many steps he was to take. At the house she said: "Tom, you must take 41 steps, and then stop." So Tom walked off, counting his steps till he had made 41, then he put down the little canary seed that stood for the planet Mercury. The globe in the library stood for the Sun; this tiny seed stood for the planet Mercury; the distance from the globe to the seed stood for the real distance of the real planet Mercury from the real Sun. Thirty-six steps farther they put down the small green pea that stood for the planet Venus; and 30 steps farther still they put down the green pea that was to stand for the Earth.

Here they stopped for a minute to think about it all. This little bit of a green pea was the huge Earth, very, very much smaller than the globe that stood for the Sun. They could not even see the small green pea that stood for Venus, nor the little seed that stood for Mercury, though they knew about where they were, of course. There were no other planets in the real space between the real Earth and the real Sun except just those two, Mercury and Venus, and space *was* almost empty, after all, as Jack had said, except for few, very few, planets that were exceedingly far apart. "Why, we

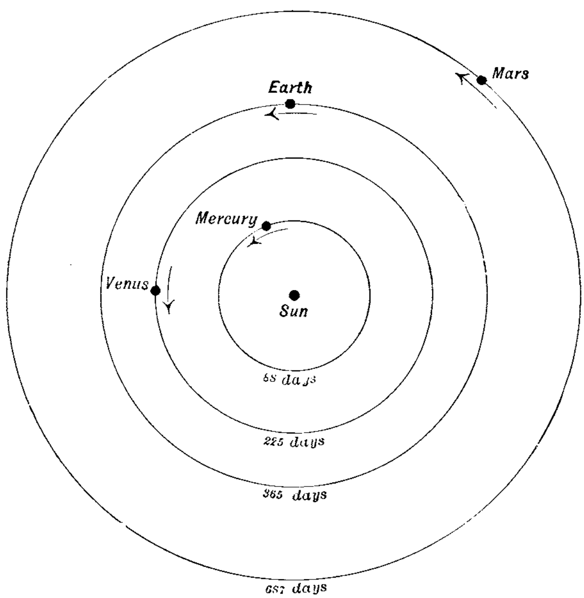

FIGURE 15

A plan of the orbits of Mercury, Venus, the Earth, and Mars.

can't even see the models of Mercury and Venus from here," said Agnes. "No," said Tom, "but if they were shining things, as the planets are, we could see them. They ought to be painted white so that the sunlight would make them glisten."

So the children went on putting the models down in the road at the right distances apart. Agnes read the right numbers from the card, and Tom walked away counting his steps up to the thousands. He got rather tired of it, but they kept on until finally all the models were put down at the right distances apart, and their map was made. By this time they were nearly a mile and a quarter away from home, and they had spent the whole morning in the work. But the work was not wasted. They really understood what they had been doing, and realized, as very few people—even grown people—do, how immensely large space is, and how few—very few—planets there are to fill it.[1]

When the children came home that day there was a great deal of talk about the map—the model—that they had made. All the older people and some of the neighbors were interested in it. They found their work had not been wasted and that they had really learned something.

[1] It is strongly recommended that the teacher should make such a model of the solar system as has just been described, with the aid of his pupils. If actually made, it will lead to a true and living realization of the dimensions of the solar system. No amount of mere class-room instruction can do this for young children.