APPLETONS' HOME READING BOOKS

THE EARTH AND SKY

HOLDEN

Appletons' Home Reading Books

EDITED BY

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UNITED STATES COMMISSIONER OF EDUCATION

DIVISION I

NATURAL HISTORY

APPLETONS' HOME READING BOOKS

THE EARTH AND SKY

A PRIMER OF ASTRONOMY
FOR YOUNG READERS

BY

EDWARD S. HOLDEN, Sc. D., LL. D.

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INTRODUCTION TO THE HOME READING BOOK SERIES BY THE EDITOR.

The new education takes two important directions—one of these is toward original observation, requiring the pupil to test and verify what is taught him at school by his own experiments. The information that he learns from books or hears from his teacher's lips must be assimilated by incorporating it with his own experience.

The other direction pointed out by the new education is systematic home reading. It forms a part of school extension of all kinds. The so-called "University Extension" that originated at Cambridge and Oxford has as its chief feature the aid of home reading by lectures and round-table discussions, led or conducted by experts who also lay out the course of reading. The Chautauquan movement in this country prescribes a series of excellent books and furnishes for a goodly number of its readers annual courses of lectures. The teachers' reading circles that exist in many States prescribe the books to be read, and publish some analysis, commentary, or catechism to aid the members.

Home reading, it seems, furnishes the essential basis of this great movement to extend education beyond the school and to make self-culture a habit of life.

Looking more carefully at the difference between the two directions of the new education we can see what each accomplishes. There is first an effort to train the original powers of the individual and make him self-active, quick at observation, and free in his thinking. Next, the new education endeavors, by the reading of books and the study of the wisdom of the race, to make the child or youth a participator in the results of experience of all mankind.

These two movements may be made antagonistic by poor teaching. The book knowledge, containing as it does the precious lesson of human experience, may be so taught as to bring with it only dead rules of conduct, only dead scraps of information, and no stimulant to original thinking. Its contents may be memorized without being understood. On the other hand, the self-activity of the child may be stimulated at the expense of his social well-being—his originality may be cultivated at the expense of his rationality. If he is taught persistently to have his own way, to trust only his own senses, to cling to his own opinions heedless of the experience of his fellows, he is preparing for an unsuccessful, misanthropic career, and is likely enough to end his life in a madhouse.

It is admitted that a too exclusive study of the knowledge found in books, the knowledge which is aggregated from the experience and thought of other people, may result in loading the mind of the pupil with material which he can not use to advantage.

Some minds are so full of lumber that there is no space left to set up a workshop. The necessity of uniting both of these directions of intellectual activity in the schools is therefore obvious, but we must not, in this place, fall into the error of supposing that it is the oral instruction in school and the personal influence of the teacher alone that excites the pupil to activity. Book instruction is not always dry and theoretical. The very persons who declaim against the book, and praise in such strong terms the self-activity of the pupil and original research, are mostly persons who have received their practical impulse from reading the writings of educational reformers. Very few persons have received an impulse from personal contact with inspiring teachers compared with the number that have been aroused by reading such books as Herbert Spencer's Treatise on Education, Rousseau's Émile, Pestalozzi's Leonard and Gertrude, Francis W. Parker's Talks about Teaching, G. Stanley Hall's Pedagogical Seminary. Think in this connection, too, of the impulse to observation in natural science produced by such books as those of Hugh Miller, Faraday, Tyndall, Huxley, Agassiz, and Darwin.

The new scientific book is different from the old. The old style book of science gave dead results where the new one gives not only the results, but a minute account of the method employed in reaching those results. An insight into the method employed in discovery trains the reader into a naturalist, an historian, a sociologist. The books of the writers above named have done more to stimulate original research on the part of their readers than all other influences combined.

It is therefore much more a matter of importance to get the right kind of book than to get a living teacher. The book which teaches results, and at the same time gives in an intelligible manner the steps of discovery and the methods employed, is a book which will stimulate the student to repeat the experiments described and get beyond them into fields of original research himself. Every one remembers the published lectures of Faraday on chemistry, which exercised a wide influence in changing the style of books on natural science, causing them to deal with method more than results, and thus train the reader's power of conducting original research. Robinson Crusoe for nearly two hundred years has aroused the spirit of adventure and prompted young men to resort to the border lands of civilization. A library of home reading should contain books that incite to self-activity and arouse the spirit of inquiry. The books should treat of methods of discovery and evolution. All nature is unified by the discovery of the law of evolution. Each and every being in the world is now explained by the process of development to which it belongs. Every fact now throws light on all the others by illustrating the process of growth in which each has its end and aim.

The Home Reading Books are to be classed as follows:

First Division. Natural history, including popular scientific treatises on plants and animals, and also descriptions of geographical localities. The branch of study in the district school course which corresponds to this is geography. Travels and sojourns in distant lands; special writings which treat of this or that animal or plant, or family of animals or plants; anything that relates to organic nature or to meteorology, or descriptive astronomy may be placed in this class.

Second Division. Whatever relates to physics or natural philosophy, to the statics or dynamics of air or water or light or electricity, or to the properties of matter; whatever relates to chemistry, either organic or inorganic—books on these subjects belong to the class that relates to what is inorganic. Even the so-called organic chemistry relates to the analysis of organic bodies into their inorganic compounds.

Third Division. History, biography, and ethnology. Books relating to the lives of individuals; to the social life of the nation; to the collisions of nations in war, as well as to the aid that one nation gives to another through commerce in times of peace; books on ethnology relating to the modes of life of savage or civilized peoples; on primitive manners and customs—books on these subjects belong to the third class, relating particularly to the human will, not merely the individual will but the social will, the will of the tribe or nation; and to this third class belong also books on ethics and morals, and on forms of government and laws, and what is included under the term civics, or the duties of citizenship.

Fourth Division. The fourth class of books includes more especially literature and works that make known the beautiful in such departments as sculpture, painting, architecture and music. Literature and art show human nature in the form of feelings, emotions, and aspirations, and they show how these feelings lead over to deeds and to clear thoughts. This department of books is perhaps more important than any other in our home reading, inasmuch as it teaches a knowledge of human nature and enables us to understand the motives that lead our fellow-men to action.

Plan for Use as Supplementary Reading.

The first work of the child in the school is to learn to recognize in a printed form the words that are familiar to him by ear. These words constitute what is called the colloquial vocabulary. They are words that he has come to know from having heard them used by the members of his family and by his playmates. He uses these words himself with considerable skill, but what he knows by ear he does not yet know by sight. It will require many weeks, many months even, of constant effort at reading the printed page to bring him to the point where the sight of the written word brings up as much to his mind as the sound of the spoken word. But patience and practice will by and by make the printed word far more suggestive than the spoken word, as every scholar may testify.

In order to bring about this familiarity with the printed word it has been found necessary to re-enforce the reading in the school by supplementary reading at home. Books of the same grade of difficulty with the reader used in school are to be provided for the pupil. They must be so interesting to him that he will read them at home, using his time before and after school, and even his holidays, for this purpose.

But this matter of familiarizing the child with the printed word is only one half of the object aimed at by the supplementary home reading. He should read that which interests him. He should read that which will increase his power in making deeper studies, and what he reads should tend to correct his habits of observation. Step by step he should be initiated into the scientific method. Too many elementary books fail to teach the scientific method because they point out in an unsystematic way only those features of the object which the untutored senses of the pupil would discover at first glance. It is not useful to tell the child to observe a piece of chalk and see that it is white, more or less friable, and that it makes a mark on a fence or a wall. Scientific observation goes immediately behind the facts which lie obvious to a superficial investigation. Above all, it directs attention to such features of the object as relate it to its environment. It directs attention to the features that have a causal influence in making the object what it is and in extending its effects to other objects. Science discovers the reciprocal action of objects one upon another.

After the child has learned how to observe what is essential in one class of objects he is in a measure fitted to observe for himself all objects that resemble this class. After he has learned how to observe the seeds of the milkweed, he is partially prepared to observe the seeds of the dandelion, the burdock, and the thistle. After he has learned how to study the history of his native country, he has acquired some ability to study the history of England and Scotland or France or Germany. In the same way the daily preparation of his reading lesson at school aids him to read a story of Dickens or Walter Scott.

The teacher of a school will know how to obtain a small sum to invest in supplementary reading. In a graded school of four hundred pupils ten books of each number are sufficient, one set of ten books to be loaned the first week to the best pupils in one of the rooms, the next week to the ten pupils next in ability. On Monday afternoon a discussion should be held over the topics of interest to the pupils who have read the book. The pupils who have not yet read the book will become interested, and await anxiously their turn for the loan of the desired volume. Another set of ten books of a higher grade may be used in the same way in a room containing more advanced pupils. The older pupils who have left school, and also the parents, should avail themselves of the opportunity to read the books brought home from school. Thus is begun that continuous education by means of the public library which is not limited to the school period, but lasts through life.

W. T. Harris.

Washington, D. C., *Nov. 16, 1896.*

AUTHOR'S PREFACE.

THIS book is intended as the first of a series of three or more volumes all treating of astronomy in one form or in another. All of them are suited for reading in the school and in the home, and they will have failed of their object if they do not inspire young readers to undertake simple astronomical observations on their own account; and if they do not, at the same time, suggest the spirit in which such observations must be made, and reflected upon, to be truly fruitful.

The earliest teaching of astronomy must be closely joined to the teaching of geography. What is already known about the earth will serve as a stepping-stone to a knowledge of the planets; and, conversely, the little we know of the planets will serve to throw light upon the constitution of the earth, and specially upon its past and future history. Any child who is old enough to study geography is not too young to begin to grasp astronomical ideas, and to observe simple astronomical phenomena.

The lessons of a child's first years, whether given at school or less formally through reading at home, are necessarily extremely simple. He should first be led to making an inventory of the visible universe—sun, moon, planets, comets, nebulæ, stars. His books will describe these objects, and he must be led by slow degrees toward verifying the descriptions by his own observations.

If a constellation is figured in his book he must be made to see that the figure exists in the book because the constellation exists in the sky. It is not so simple as it appears to fix in a child's mind the fundamental fact that it is Nature which is true and the book or the engraving which is a true copy of it. "It says"—is the snare of children as well as of their more sophisticated elders. The vital point to be insisted on is a constant reference back from words to things. After the things are understood we may go back to words again, and we can then restate the matter in hand in briefer, apter, and more technical forms.

The early studies of a child should be utilized to lay the foundations of future advances. For example, the child should have his attention directed, almost at the beginning, to some of the more striking constellations—to the Great Bear, to Orion, to the Pleiades. During the whole lifetime of the child the naming of the constellations should go on. It is not so much that these names are of any great importance, though to know them is a source of real pleasure. But in tracing their outlines through the sky, by the eye, the mind becomes intent on allied matters, and the thoughts reach out to better things.

Very many children will take a lively interest in the identification of stars and in tracing the course of the planets among the constellations; and this interest deserves to be fostered for its ultimate, as well as for its immediate, results. The delight of discovery is hardly less poignant to the child who has really observed for the first time that the stars in their courses really move about the pole from east to west, than to an astronomer of maturer age who makes some real step to advance his science.

Early in the child's life his attention should be directed to the observation of the moon's face, of her phases, and of her motions. After the unassisted eye has done its part the use of a common field glass will open a new world. Galileo was not better equipped. An opera glass, a watch, a straight stick for a gnomon, or for testing the allineations of stars or planets, bits of colored glass for looking at the sun (using care in this matter), terrestrial and celestial globes, if they are to be had—these are the simple pieces of apparatus that the child should be encouraged to successively acquire and utilize.

It is very important to introduce such aids slowly, one by one. The eye should be faithfully employed before the opera glass is used. Thoroughness is a scientific (and a moral) virtue which a child can not acquire too early; and the simplest beginnings of astronomical acquirement may be used to impress the habit on a child's character.

Not only should observations be made as thoroughly as possible with the means at hand, but they should be recorded neatly, accurately, and exhaustively. The child should feel a responsibility for what he records, and he should authenticate his pages or his drawings by his signature. A signed page will soon come to mean to him an observation that has been carefully and correctly made, and that can be depended upon ever after.

The observation of the morning and evening stars will serve as an introduction to the mapping of the apparent path of a planet (Mars, Jupiter, or Saturn) among the stars. The revolution of the moon will suggest the origin of the month, and thus may introduce some consideration of the calendar—a knotty steadily cultivated. The circles exist, first of all, in the heavens, and the book or the globe only exist because the circles are there. The ground idea of an eclipse is very simple if it is studied out of doors with real shadows. Afterward the drawings of a book will mean something real.

The power of conceiving geometric relations of the sort can be wonderfully cultivated even in young children. Just as descriptive-geometry gives the very best training to advanced students of mathematical form, so this habit of representing geometrical relations in the mind is of prime importance to the beginner in astronomy.

All the early teachings of children in Nature studies should, in general, be directed mainly to training their eyes to observe correctly and to leading their minds to genuine reflection. What they learn of the facts of astronomy is of comparatively little account. The real matter is so to use the universe as to train each small mind to observe, to register, and to reflect.

Astronomy is especially fitted to serve this end, and it has been my endeavor in these volumes to utilize it to the best advantage of the child.

NEW YORK, *January, 1898.* E. S. H.

BRIEF ANALYSIS OF THIS BOOK.

THE volume is written as a conversation with a young lad. He is first shown how he may know for himself that the earth is not flat, though it certainly appears to be so. The next step is to show him that he may know that the earth is, in fact, round; and that it is a globe of immense size. Its situation in space is next considered, and the child's mind is led to some formal conclusions regarding space itself. The sun and the moon are next treated, and the child is encouraged to observe the moon's phases, and shown exactly how he may best do it. This leads him to inquire why it is that the bright part of the moon changes its shape from night to night. He is put into a position to solve this problem for himself. The motion of the stars in their courses is next considered, and the child learns for himself that the earth turns round once in every day. It is believed that nothing here presented is too difficult for a young child to comprehend, and that the bases of scientific habits are laid down in a manner not to be misunderstood.

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THE EARTH AND SKY.

CHAPTER I.

THE EARTH IS NOT FLAT.

Well, Master Frank, as you wish to learn something about astronomy, suppose we begin our first lesson. Astronomy is the science that tells us about the sun and the moon and the stars as you know already.

But let us first talk a little about the earth. By and by we will talk about the stars. They are so very far off that we shall have some trouble to understand much about them. But we are living on the earth, and if we take pains we can find out a great many things about it. And what we find out will be interesting, too.

Of course, *you* know that the earth is not really flat, though it certainly seems to be so.

It is really a huge ball, larger than anything you can imagine. You know that very well. But just knowing a thing is not enough. You must be able to say *why* you know. And that is not so easy. Taking pains and knowing why is pretty much all of science, and we might as well begin at once.

I am going to ask you what you would do if I should introduce you to one of those little Eskimo boys that Lieutenant Peary found living on the flat ice in the arctic regions, and if I should say, "Now, Master Frank, here is a little boy of your own age who doesn't believe the earth is round at all. He speaks English, you know. And he is quite a bright boy, too. But he says the earth *looks* flat, and that it must really *be* flat"—what would you say to that? How would you make him understand? It will not be of the least use to tell him that all the people you know—papa, mamma, Aunt Clara, and your school-teacher—say that it is certainly so.

He would probably say that these are very nice people, but that his eyes tell him that the earth *looks* flat. And shall he not trust his own eyes? It will be of no use to say that he is stupid, and that he has got to believe what he is told. He is not stupid. He just does not know. And we have got to teach him.

If we really know about it ourselves, we can do that by taking enough pains. But I think it will take quite a long time. Suppose we try it together. You could do it by yourself, no doubt. But perhaps we can do it more quickly if we both try. Recollect that this little Eskimo boy will not believe a single thing unless we can make him see with his own eyes that it is just as we say it is.

There is one thing that we might do that would certainly convince him, though it would take a long time and would cost more money than we could possibly spare. We might make him sail quite round the world in a ship, and come back to us here and tell us where he had been, and how he happened to be back where he started from. Just let us see how we might do this if we only could.

In the first place, we should have to go to the bank and get a great deal of money—as much money as would be needed to hire one of the ocean steamships, with her captain and all her men, for three or four months. And we should have to buy coal for the engines and food for the men, and all sorts of fittings for the ship. If a rope should break, or be lost overboard, there must be a new one all ready to put in its place.

Then we should have to go down to a sea-port and find a steamer to hire. No doubt one could be found. There are always plenty of them. We should have to tell the captain just what we wanted him to do. "The whole ship and all the men on it are wanted, Captain, just to take this little Eskimo boy round the world and to bring him back to New York."

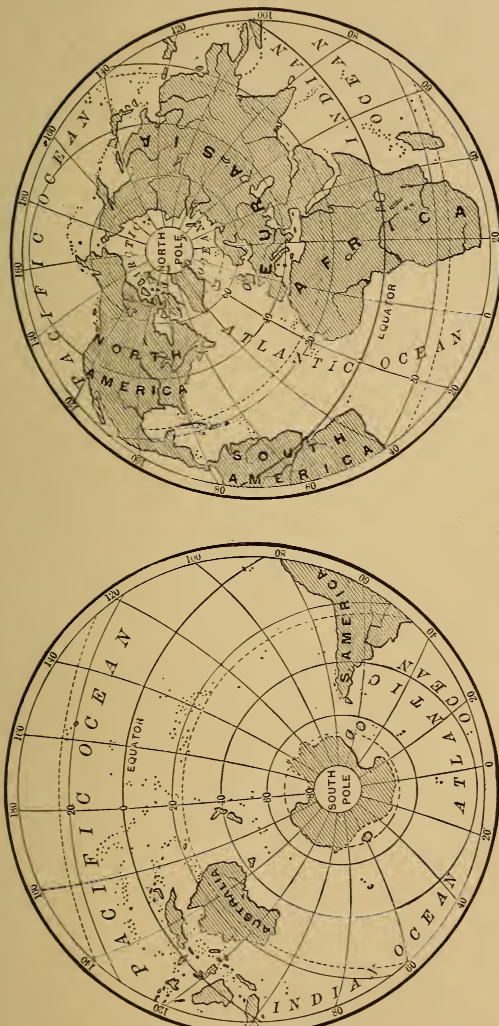
"But why in the world," the captain would probably say, "do you want this little boy to take this long voyage of twenty-five thousand miles?" "Oh, just to prove to him that the world is, in fact, round and not flat." I suppose the captain would be astonished, don't you? But he would have to go, all the same.

A large steamship, fit to sail round the world.

We should put our boy on the ship, and he would sail away out of the harbor, past Sandy Hook lighthouse to the east.

You and I can follow on the map the way the ship would go. In the first place they would sail to the east, across the Atlantic Ocean, through the Straits of Gibraltar, till they got into the Mediterranean Sea; and then nearly the whole length of this sea to the Suez Canal; and down the Red Sea to the Indian Ocean; and round the end of India to the Pacific; and, always sailing toward the east, across the Pacific Ocean and around Cape Horn into the Atlantic again, and finally back to Sandy Hook once more. They would have to stop for more coal and for fresh provisions at quite a number of places, and they could hardly arrive at Sandy Hook before three or four months.

In the meantime you and I might amuse ourselves in many ways, and almost forget our ship, and the little boy. But finally there would come news that the ship was coming in, and we should go down to the wharf to meet



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Two hemispheres of the earth. You must try to trace out the track of a ship sailing round the world.

it. What a lot of things our little boy would have seen in his long voyage! What a wise boy he would have become! He would certainly know one thing, at any rate. He would know that you could sail quite round the world, and that it was so large that it took something like four months to make the voyage.

But this would be a very costly way to teach a single boy, and to teach him so little, after all. There are much better ways, and we shall have to think about them.

CHAPTER II.

THE EARTH IS ROUND.

INSTEAD of sending our little Eskimo boy on a long voyage round the world to prove to him that the earth is not flat, we can do better. We can all three go to the seashore and watch the ships sailing away and think about what we see.

This picture shows us what we might really see in any harbor like New York, or Boston, or San Francisco. The ships are sailing away to foreign countries. Some of the ships are near and some far off, and there must be other ships, beyond the edge of the sea, that we can not see at all. They sailed away this morning and are out of sight now. They are already beyond the edge of the sea. There is a name for that line where the sea and the sky meet. It is called the *horizon* line —the hor-i′-zon, with the accent on the i.

It is the line where the sea and the sky

Ships sailing out of a harbor. The more distant ships look smaller. The hull of each ship disappears first, as she sails away. The uppermost sails are seen longest.

meet. You see that it *is* a line. At least it looks like one.

Now let us look at the ship that is nearest to us. What do you see? (Look at the picture, which is a true one.) You can see the whole of this ship, with all her masts, her three sails on each mast, and her flag. It is a French flag in the picture—three upright bands of red, white, and blue really, though the colors are not given. Those are the French colors. You can see the hull of the ship—the wooden ship herself, that is—and her tall masts. She is so near the shore where we are that we can see her plainly.

Now look for a moment at the ship next to her. This one is farther away and you do not see her so plainly. She looks smaller, too. And the third ship looks smaller still, and so on. That is something to remember. The farther away a ship, or a house, or a locomotive, is the smaller it looks. You know that already, of course, and so does every Eskimo boy, though very likely he has never said it in plain words like that. The second ship is so far away that she looks smaller. But we can see the whole of her. The hull is there, and the masts and the flag, too.

Now let us look at the third ship in the picture. Recollect that the picture is a true one. Real ships near a real shore would look just so. A photograph of ships would be a true picture, and it would show them just as this drawing does. The third ship looks smaller than the second one because it is farther away. And the hull of this ship is not to be seen. We know that the hull is there, of course.

Let us look at the fourth ship now. It is smaller, of course, and not so plain. But you can not see the hull at all. The sails are there and the masts, but where is the hull? Of course the hull is really there. All ships have hulls, and this one has a hull, surely. But what is the reason we can not see it?

Something has come between our eyes and the hull of this fourth ship. And you must notice that while we can see her topsails, the lower ones are partly hidden too. At the left-hand side of the picture there is another ship almost out of sight. You can not see her hull. Her lower sails are quite out of sight, and even the middle sails are nearly hidden. It looks exactly as if she were going down over the farther side of a hill.

If we should stay here and watch all these vessels we should find that pretty soon the fifth one would vanish entirely. She would seem to slip down over the farther side of some hill. She would go beyond the horizon line—the line which is just at the meeting of sea and sky. Soon she would be quite out of sight. Her middle sails would vanish first, and then her topsails, and she would soon be quite gone and there would be nothing to watch.

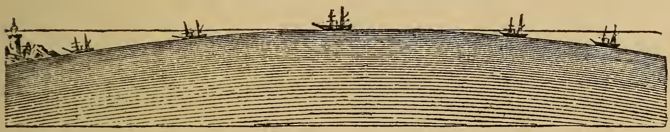
We might watch the next ship in the same way; and the same things would happen, in just the same order. The middle sails would vanish first, and then the top ones; and she would be gone too. It would be the same for every one of the ships. When a ship is near we can see the whole of her. We can see her hull, her masts, and the three sails on each mast. As she sails away from us we see less and less of her.

The hull disappears below the horizon line first; then we lose sight of her lower sails;

next the middle sails disappear; at last the upper sails are seen no longer, and the ship has vanished from our sight. These things will always happen, in just this order, if you watch for them. The tallest things will be seen longest. The sails that are nearest to the water vanish first. The tallest sails vanish last. No matter when you come to the seashore you will always see this happen.

If the sea were really flat, as it looks, these things would not be so. The hull of a ship is the biggest part of her, and on a flat sea it would be seen longer than any other part. But if the sea is rounded, like a part of the outside of a huge globe, things would be as they are in this next picture.

Suppose we were up in the tower, at the left-hand side of this picture, looking out over the sea, and that there were quite a number of ships, just as the picture shows them. If we took a long stick, like a cane, and held it level we might look along it. If the cane were suddenly to grow miles long it would look like the straight line in the top of the picture. The cane would be perfectly straight, and we should be looking along it. The ships would be sailing over the water just as in the picture.



This picture shows a part of the curved surface of the sea. A person at the top of the tower will see the whole of the middle ship in the picture, but only parts of the two ships to the right. The further away a ship is, the less he will see.

The nearest ships would be seen completely. The whole of each near ship would be seen. Some of the far-away ships would be hidden, as in the picture, and only the highest parts of these far-away ships would show. The lowest parts would be hidden, so that if the sea were really curved like a globe and not flat, just the same things would happen that really do happen.

The first picture showed exactly what can be seen any day, by any one, anywhere at the seashore. The ships do vanish just that way —the lower parts first, the higher parts next, the highest parts last. The next picture shows that *if* the sea was curved and not flat these very things *would* happen just as they do happen. If the sea were rounded the far-away ships would glide away behind the rim of the world.

We have found a reason for what happens. If the sea is really rounded the rim of it will hide ships that sail behind it, just as ships are really hidden in fact. Even a little Eskimo boy can understand that. Let us give him a short time to think about it.

CHAPTER III.

THE EARTH IS A LARGE GLOBE.

There is a very simple experiment which you can try, Master Frank, the next time you go bathing in the ocean. If you try it, it will prove that the surface of the sea is round. Or you can try it in a large lake. A river will not do. Most rivers are so narrow that the earth does not bend enough out of a straight line in the little distance across them from shore to shore.

You can try it in the ocean on a perfectly calm day when there are no waves. Stand on the beach first, just at the edge of the water, and look out to sea. If there is a boat—a row-boat—a mile or two out, you can see the whole of it—that is, all of it that is out of water, of course. Your eye is some three feet above the ocean level.

Now wade into the sea until the water is nearly up to your chin and look for the boat. You will only see a part of her; the sea has curved in between you and the boat and hidden the lower parts of the hull. The higher parts can easily be seen still, but the lower parts are hidden.

So long as your eye is close to the water the rounding of the sea will hide something. The water curves up like a little hill in front of you. When you stand on the beach at the edge of the water you are able to look over the top of the hill, just as if you were in the tower in the last picture. (Turn back and look at it, please.)

If a man were as tall as the tower his eye would look out over the ocean along the line that is drawn all across the picture. If he were very short, so that his eye were at the foot of the tower, he would see the whole of the first ship, part of the second one, and only the top of the masts of the third one.

You can prove this for yourself if you will hold the straight edge of a card above the left-hand side of the picture. Above it. And you must hold the card so that one corner of it touches the very foot of the tower—that is where the man's eye is now—and so that the bottom edge of the card just touches the water somewhere near the second ship.

The man at the foot of the tower looks along a line which is just the same as the line of the card. The rim of the ocean is for him about where the second ship stands. Everything nearer to the tower than the second ship he sees very well. Everything farther off is partly cut off from his sight. I think this will be plain. And even our Eskimo boy can be made to understand this if you explain it to him slowly and patiently.

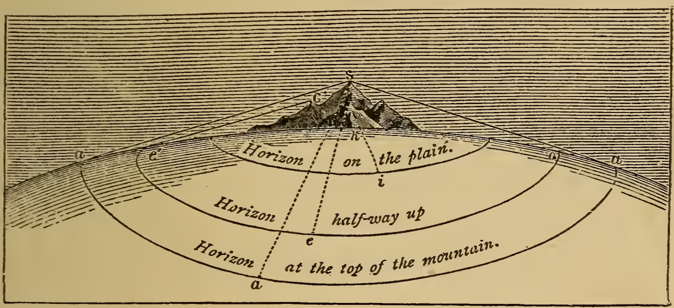
You may try to answer another question. Suppose a man to be in the tower so that his eye were in the very top of it, what would *he* see? Take the card again; put it above the picture so that its left-hand lower corner is just at the very top of the tower, and move its lower edge till the card just touches the sea, about halfway from the third to the fourth ship.

The rim of the sea for the man in the top of the tower is where the lower edge of the card touches the sea—just about halfway between the third and fourth ships. He will see the three nearer ships very well, the farther ones he will only see partly. I think your Eskimo friend can understand this, too. Let us give him something a little harder to think about.

This picture shows things as they would be if we three could travel up a high mountain with no other mountains round it to shut out the view. It might be a mountain in the midst of the sea. Now, if we first went to the very top of it (where there is a little *s* in the picture) and looked around, what should we see? Remember there is nothing to hide the view—no other mountains nor hills. We should be able to look off a long, long way. If the mountain were a mile high we could see the earth in every direction for about a hundred miles.

We could see just as far in one direction as in every other. Just as far to the south as to the north; just as far to the east as to the west.

There is nothing to hide the view. The largest circle, *a a a* (you must find these three *a*'s), is the horizon line for us at the top at *s*. Everything in the sky we can see. And we can also



This picture shows that people at different heights have different horizons. A person at the top of the mountain will have the largest horizon. He will see the most of the surrounding country. A person on the side of the mountain will see less country, and a person on the plain at the foot of the mountain will see the least of all.

see everything on the surface of the ground between the circle *a a a* and the foot of the mountain.

If we could take a rope a hundred miles long and fasten one end of it to the very summit of the mountain, at *s*, and carry the other end down to the ground; and if we could always keep the rope straight like the two lines *s a* and *s a* on the left- and right-hand sides of the picture; and if then we could walk along, always keeping the rope straight, we should find that we were walking along a circle, like the line marked "Horizon at the top of the mountain" in the picture.

Of course, we can not really have a rope a hundred miles long, and if we could it would be entirely too heavy to carry; but you can imagine it, can't you? The three lines, *s a*, *s a*, *s a* (a different *a* each time), will show how the rope would look if only we could make it and stretch it out.

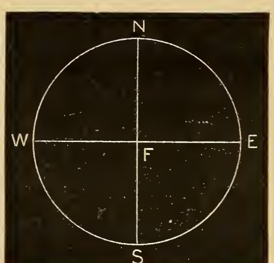
If we should climb down to the place marked *c* (on the left-hand slope of the mountain) we should find that we had quite a new horizon and one not nearly so wide. At the place *c* we should look along the line *c e′* to the earth. The point *a* and all the circle *a a a* would be quite hidden. You can imagine a rope stretched from *c* to *e′*, and a boy walking round the circle *e′ c o*—"horizon halfway up."

And if we should climb down to the very foot of the mountain (where the letter *k* is in the drawing; you must find it, please), the new horizon would be much smaller. It is marked on the smallest circle "horizon on the plain." Once more you can imagine a shorter rope here, like *k i* in the picture, and a boy walking around the circle marked "horizon on the plain." Of course we should make the boy walk round the whole circle, not only round the half circle drawn in the picture. You see that it is only a half circle? The other half of the circle is hidden behind the earth itself in the picture. The earth is not transparent—you can not see through it—and we are obliged to draw the picture that way.

A man's eyes are about five feet above the ground, and his horizon line is less than three miles distant. When he climbs a mountain a mile high he can see in every direction about a hundred miles. That is one of the reasons why men take so much trouble and run such risks to climb high mountains. The views they get are splendid and very wide.

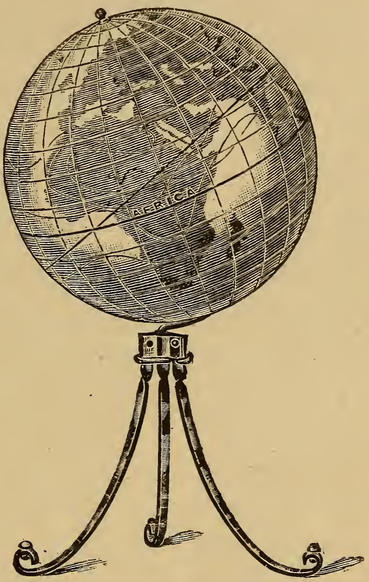
Your dog's eyes are only about a foot from the ground. Did you ever think how much he misses, just because he is not tall like you? The next time you are out in an open field, get down on all-fours, like a dog, and look about you and see how small the world has become. If you stand up in the center of a very large field you can see about two miles in every direction; and your father, who is taller, can see nearly three miles. And the people on the top of a mountain a mile high can see about one hundred miles.

Look at the last picture once more, please. If you were at the very top of the mountain, at *s*, you would see about you in every direction, and the rim of your world would be the line marked "horizon at the top of the mountain." You could see just as far toward the north as toward the south. Your horizon line would be a circle then.



If you were at *F* and looked to the north you could see to *N* and no farther; if you looked to the south you could see to *S* and no farther;

if you looked east or west you could see to *E* or *W* and no farther. That circle, *NESW*, would be your horizon line. Half of it is shown in the picture of the mountain.



A school globe that shows the round earth with its continents and oceans. The lines are drawn on the globe for convenience to show the latitudes and longitudes of cities. Of course there are no such lines on the real earth.

Your horizon line on the earth, whether you are at sea or on a large plain, is always a circle. If you look up in the sky there is no horizon there at all. You can look off as far as the moon and the stars. These are facts which you can observe at any time and anywhere on the earth. The earth itself is of such a shape that everybody's horizon is always a circle. So the earth must be a globe, and we must be living on the outside of it.

We know that the earth is a very large globe too. If we travel round it on a steamship, like the little Eskimo boy, we can count up at the end of each day how many miles we have sailed, and add up all the miles of all the days when we get home again. We should find that it was about twenty-five thousand miles round the earth where it is largest.

Or, we might start from New York on a railway train, and go directly west some three thousand miles to San Francisco, and by steamer to the eastern side of Siberia, and across Siberia by railway and wagon to Europe, and across Europe to France by railway, and back from France to New York by steamship. You should trace out this journey on the map. If we should count up all the miles of all the days (some eighty days) of this journey we should find, just as before, of course, that it was some twenty-five thousand miles round the earth.

So that the earth is not only a globe but it is also a very large globe indeed. If you were to try to walk from New York to San Francisco, only three thousand miles, it would take nearly a year for you to do it. And it is more than eight times farther round the whole globe. If it were all dry land you might walk round it in seven or eight years. That *would* be a long walk. And the earth is certainly a large globe, not a small one.

Now is not all this very plain? Of course *you* understand it; but I mean would it not be easy to explain all this to any Eskimo boy who wanted to know about such things? You would need to thoroughly understand it yourself and, to be very plain and very patient, and you could explain it to anybody—to an Eskimo boy, or to anybody at all. It doesn't matter what anybody says about this now; you know it for yourself. If you have a new hat or a new gun you can lose them by accident, but you can't lose knowing a thing that you have once really learned.

Before we stop speaking about the earth I want to tell you one thing more. Very many men have sailed round the earth, and thousands and thousands of men have wandered over nearly every bit of dry land on it. Every one of these men everywhere has noticed that the earth was quite separated from every other globe. It does not touch the sun; it does not touch the moon; it does not touch the stars. On the contrary, they seem to be very far off from every part of the earth; and so they are.

This large round earth of ours is quite by itself; it touches nothing else in the sky. Just think about this a little, and recollect that you are a small and very nice boy on the outside of an exceedingly large globe, and that this globe is all by itself. It does not rest on anything. It touches nothing. Even the moon is very far away, and we are nearer to the moon than to anything else in the heavens.

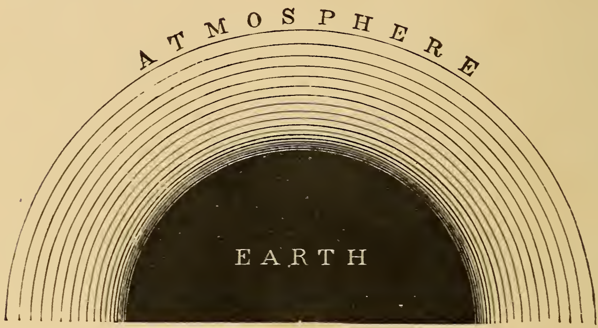
CHAPTER IV.

THE EARTH IN SPACE.

It is certain that we live on an earth that is round, and that is exceedingly large. If the seas were turned into dry land, so that you could walk all round the earth, it would take seven or eight years for you to do it. And this round earth is all by itself. It does not touch the sun, the moon, the stars, but is, in fact, far away from any one of them.

You stand on the solid earth itself. Now what else is around you? Well, there is first the air that you breathe. You know it is there, although you can not see it. You can feel it when you breathe it. Is there any other way that you can feel it? Yes—of course the wind that blows against your face is nothing but air moving. When there is no wind you hardly know that there is any air at all, but when the wind blows there is no doubt about it. Some one has made a kind of a picture of the earth and the air, which is copied here.

The earth is the black globe in the middle and the air is the circles in the drawing.



In the picture thay have given only a part of the earth, leaving you to imagine the rest. You can do that, can't you? And you must think of the earth as a globe with air all around it. In the picture they have called the air "atmosphere," which is the scientific name for it. It really means *vapor-sphere*, that is, the sphere or globe that holds the vapor, the fogs, the clouds, and the air.

This is not a real picture, like a photograph, which shows just how the earth and its atmosphere would look to a person on the moon for example; it is rather more like a memorandum which you make in a book. It helps you to remember how things really are. You remember the memorandum, but you must see the things themselves "in your mind's eye."

You know you've got a way to see with your mind, and you can see that way whether your eyes are open or shut. It will make no difference at all. You can imagine them. You must imagine the earth, then, Master Frank, to be a huge globe. You are a little speck somewhere on its outside surface. All around the earth is a thick layer of air, and you are in the air just as if you were standing in invisible water. The ocean water is visible, and if you get into it you are wet. If you go to the bottom of it you are drowned.

There is an ocean of air all around the earth, over the land just as well as over the sea; and you and I and all of us are walking about at the bottom of this ocean of air. We live at the bottom of the ocean of air just as crabs live at the bottom of the ocean of water. The ocean of water is not so very very deep —not often more than three or four miles deep.

The ocean of air over our heads is very much deeper. It is more than a hundred miles deep; more than a hundred miles high above our heads. The birds fly about in it just as the fish swim in the ocean, and we walk about on the bottom just as crabs walk about on the bottom of the ocean.

What do you suppose is above the air? Well, there is nothing above it. As you climb up the mountain there is less and less air to breathe. Try to do it sometime and you will find out! When you have climbed up two miles or so, there is so little air that climbing gets to be very hard work indeed.

If you still go on climbing for another mile you will be three miles high. It is very cold there, and the rocks are always covered with snow. The air is very thin. There is scarcely enough of it to breathe. It is difficult to take even a few steps. The highest mountains in North America, in Hawaii, and in Switzerland are about three miles high. In India there are a few huge mountains, four and five miles high.

Balloons have been sent up with men in them to nearly six miles, but sometimes the men have died for want of air, though now we have learned how to be safe even so high as this. Even the birds do not fly so high as this. Balloons with no men in them have been sent up as high as ten miles! Think of that! It is horribly cold at that height, and there is scarcely air enough to float the balloon. Of course you know that a balloon floats in the air exactly as a cork floats in the water.

The higher you go in the air the less air there is. By and by there is no air at all, and the space is empty. All around the earth is its bedquilt of air (we may call it a bedquilt because it keeps the earth warm), and outside of this there is nothing at all.

We must have a name for this empty

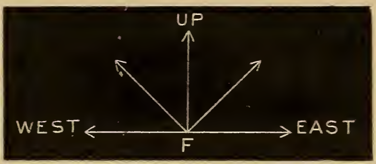
space—for this space where there is nothing at all. Let us call it just—*space*. Space is everywhere. The earth seems to float in space just as a balloon floats in the air, just as a cork floats in the water.

Suppose you had a wonderful gun that could shoot a bullet that would never stop, but which would go on forever. If you shot the bullet straight up in the air it would go on and on quite through the air, ten miles up, fifty miles up, a hundred miles, till finally the bullet had left the earth and all the air behind it, and had come into what we call space. It would still go on. There is nothing there to stop it. And it would go on forever—our bullet. So far as we know it would go on and on, and on, forever. What is to stop it? There is no outside to space. It is all inside.

If you held your magic gun straight up the bullet would go on forever in that direction. If you held it nearly level, pointing to the east, and shot another bullet, that one, too, would go on and on forever, through the air, and out beyond it into space, and on, and on, and on.

What is to stop it? And if you shot another bullet to the west, and another to the north, and another to the south—all these bullets, too, would go on through the air—out beyond it, and on, and on, forever. What is to stop them?

This picture might show Master Frank standing at F and pointing his magic gun up, or to the east, or to the west, or anywhere, and shooting magic bullets out through the air into space. No matter in what direction you shoot them, they will go on forever. There is nothing to stop them. Space goes on forever in every direction, no matter which way you point.



If you should take your magic gun to San Francisco, or to Asia, or to Cape Horn, or to the arctic regions, or anywhere, and if you should shoot a shower of magic bullets in every direction, from every one of these places, each one of these bullets would go on and on forever with nothing to stop it. Space is everywhere, in every direction, and it has no end. Did you ever think of this, Master Frank? Space is like an endless ocean of nothingness, and the earth is floating in one little part of it.

We said the earth was very large just now when we were talking about it. And so it is. It is much larger than many Franks, much larger than many New Yorks, much larger than many Americas. But what a very little speck it is inside of this huge, immense, gigantic space in which it floats! You could walk round the earth in seven or eight years we said. But seventy lifetimes of walking would not take you far into space. Suppose your magic bullet went a mile in a minute, which is as fast as the fastest railway trains, it might go on and on for ever and never come to the end of space, no matter which way you shot.

One of the wise men of old times* was once talking about space. Some one said that space had an end to it—that space had a limit—a boundary. On this side of the limit

* Lucretius.

there was space; on the other side no space. "Well," said Lucretius, "I stand at the limit with my lance, and I throw my lance outward. Where does my lance go?" Of course his lance would go into space, and of course there was no such limit to space at all. Space is everywhere and contains everything. It has no boundary. The earth and all of us on the earth are floating in space. The sun, the moon, and all the stars are floating in space.

CHAPTER V.

THE SUN.

Now, Master Frank, the question is, Have we any neighbors in this ocean of space? Tell me if you know of any other things beside the earth that are floating about in space. "Well, there is the sun?" "Yes, there is the sun; that is one neighbor." "And there is the moon." "Yes, the moon; another neighbor." "And the stars." "Yes, more neighbors, millions of them. Are there any more that you can think of? No more? Well, you have thought of nearly all of them. The sun, the moon, and the stars are our neighbors." They are not very close ones. They are very far away; but they are all the neighbors we have. They are all of them floating in space just as we are. What shape is the earth? We found it was a globe, you know. Well, the sun is a globe, too—a globe of the same shape as the earth, only very, very much larger.

How can you know that the sun is a globe? Suppose you wait for a foggy day and then look up toward the sun. You can see it through the fog, and you can see its shape. It is quite round. At sunset and at sunrise, too, it is round. If you take a piece of common window glass and hold it over the flame of a candle, and smoke it evenly all over, you can look at the sun through it. Only you must be careful not to hurt your eyes.

You will see that at any and at every time of day the sun is round. Now, a thing that always looks round, as the sun does, no matter when or where you look at it, is probably a globe. And the sun *is* a globe, as I will show you in a different way some day. Not only is it round, but it shines with its own light as an electric light or a candle does. The sun shines by its own light. The earth does not shine at all.

But before we go any further let me tell you exactly how to smoke your piece of glass in the best way, without burning your fingers. You must first get the glass. Choose a piece about three inches square. Then borrow a pair of pincers from somebody, and hold the glass in the pincers. Do not hold it too tight or else you'll break the glass and spoil it.

Now hold the glass flat over the flame of a candle and several inches above it, and move the glass about a little. The smoke from the candle will make a thick, black film of soot on the glass; and you must keep moving the glass about till the film is quite thick and very even, with no holes in it. If the sun shines through any hole that a careless boy has left, it will ruin his eye, so you'd better be careful!

The very best way to smoke the glass is not to use a candle at all, but to use camphor instead. Buy a piece of camphor, about as big as a green pea, from the druggist, and put it in a saucer, and set it on fire with a match. It will send out a thick smoke, which is just the thing for smoking glass. Hold the glass over it till the whole glass is covered with a thick film of soot, quite evenly, with no holes in it. Then you can look at the sun through it safely. Perhaps, to be *quite* safe, you may better let papa or mamma or Aunt Clara try the glass first, and when it is just right you can use it.

You should hold the smoked side of the glass away from your face, and the unsmoked side toward your eye. "What for?" Can't you guess? So as not to get the soot on your nose, my boy.

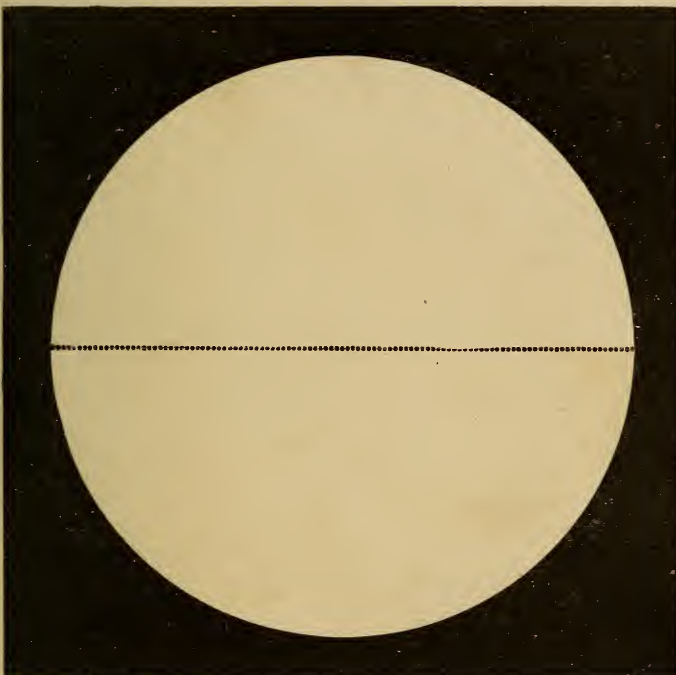
Another way to see the sun even better than through smoked glass is to buy from an optician (a man who makes or sells spectacles, and so forth) two or three pieces of colored glass (red is the best). If you look at the sun through one piece only it will be too bright and will hurt your eye. Let some of the older people try first and they can decide whether you will need three pieces or only two. You can tie the pieces together with strings, or fasten them with rubber bands.

Now you have a way of looking at the sun safely. And when you look at it you will see that wherever and whenever you look, the sun is round. And if it always and everywhere looks round it is probably a globe. I will show you in a different way sometime that it really *is* a globe, and a very large one.

The picture on page 43 (if you forget about the line across the middle of it) shows how the sun looks through a smoked glass. In the center of the glass is the round sun, which looks white or yellowish through a smoked glass or through a fog. All around it is space, which looks blackish through the glass. No light comes from empty space. If you are looking through a red glass the space around the sun will be red, and the sun itself will be a far more brilliant red.

Just now I said that the sun was an exceedingly large globe. Scientific men know just how large it is. Sometime I will tell you how they know, but you must take my word for it now. It is so large that if you could lay one hundred globes as big as the earth across the sun they would not reach from edge to edge. It would take one hundred and nine of them to do it.

The line across the face of the sun in the picture is a line of one hundred and nine little dots. Count them. If the earth



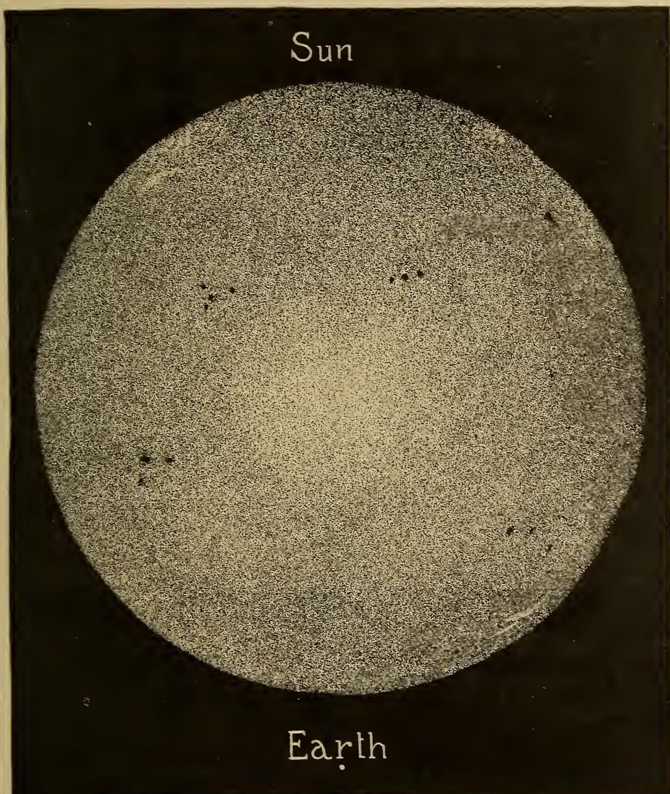
This picture shows one hundred and nine little black dots laid across the white circle. If each of these little black dots were as big as the whole earth, the white circle would be just the size of the sun.

could be taken and put just in front of the sun it would be no larger than a single one of those little dots. Think of it! This earth that we said was so large (and that *is* large to us) is only a speck alongside of the sun. It would take one hundred and nine earths placed side by side to make a line across the sun's face!

The sun is a globe, you know. It is solid and not flat like the picture. How many little globes like one of those little black dots do you think it would take to fill up the whole globe of the sun? If the sun were a hollow globe with a hole in the top how many earths would you have to drop in through the hole before the hollow globe of the sun was filled?

You can see that thousands and thousands of earths would be needed. I will tell you that it would take more than a million of them—more than a thousand thousands of them. Think of it—first there is one earth—then a heap of ten earths—then a hundred such heaps. Let us imagine all these hundred heaps put into one large pile.

Now we have a thousand earths in a huge heap. We should have to make a thousand of such heaps in order to get enough to fill up the hollow globe of the sun. You can see from the picture on page 43, which is a true one, that it



would take very many of the little black dots to fill up a hollow globe as large as the white circle.

Great as the earth seems to be the sun is immensely greater; and even the sun is the merest speck in comparison to space.

The picture on page 45 is worth looking at, Master Frank. It is a drawing that shows how the sun looks in a small telescope; and down at the bottom of the picture is a little white dot which shows how large the earth is in comparison with the sun.

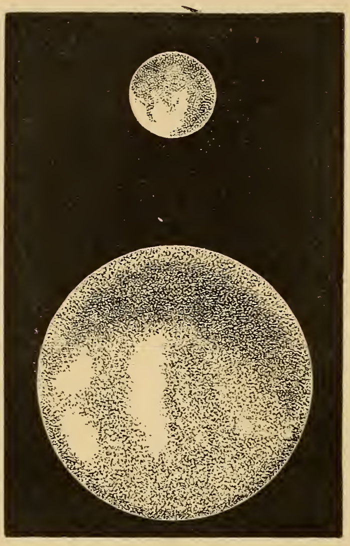
It is another way of showing how vastly larger the sun is than this earth on which we live. On the sun's face are some dark spots—sun-spots they are called—which I shall tell you about some day. Notice that some of them are very much larger than the whole earth. The sun has spots on his face bigger than the earth; and those are only the spots; what an enormous face!

CHAPTER VI.

THE MOON.

One of our neighbors in space is the sun. Another one, our nearest neighbor in fact, is the moon. You have heard that the sun is a huge globe, and that it shines by its own light as an electric light shines. The moon is a large globe, too, not so large as the earth, but still very large. The moon does *not* shine by its own light. It simply reflects the sunlight, just as a mirror would reflect an electric street lamp which shone on it. Whenever the sun shines on any part of the moon it is daytime on that part, just as it is daytime on the earth wherever the sun is shining.

A few pages back we had a picture showing how very large the sun was compared to the earth. It would take more than one hundred earths put side by side in a straight line to reach across the sun's face. This picture



Comparative sizes of the earth and the moon.

shows that the earth is very much larger than the moon, but it would not take one hundred moons side by side to reach across the earth's face. Three moons side by side in a line would not quite reach across. Four moons side by side would be enough.

It is a little less than eight thousand miles through the earth in a straight line from side to side. And it is a little more than two thousand miles through the moon, from outside to outside again. You see the moon is certainly a *large* globe. It is two thousand miles through, and more than six thousand miles round. A string that was long enough to go round the moon's globe once would be more than six thousand miles long. If you should cut the string in two in the middle each one of the parts would still be long enough to reach from New York to San Francisco.

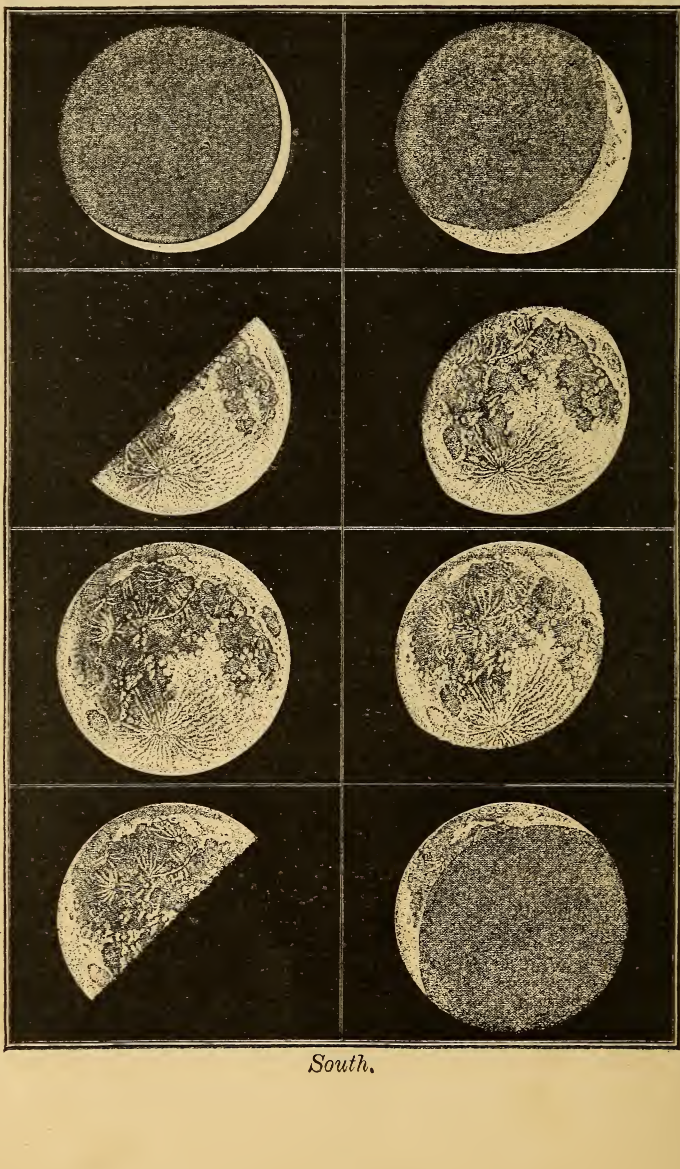
Here is a picture. I wonder if you know what it means? We are talking about the moon, you remember. Now what has this picture got to do with the moon? Oh, you recollect now. The moon is sometimes a thin sickle-shape, like the upper left-hand picture. You have seen it so in the early evening just after sunset. Yes, that is the new moon. The thin sickle (we call it a *crescent*) is the "new" moon, and the rest of the dusky circle we call "the old moon in the new moon's arms." You've heard them spoken of in that way, haven't you? Now look at the upper right-hand picture. The sickle is much fuller, but you can still see the old moon.

In the third picture the moon seems to be cut exactly in two. The bright part that you see is just half of a globe. The other half seems to be quite gone. There is no light there.

In the fourth picture the bright part has

North.

East.



West.

South.

grown larger—much larger. And in the fifth picture the moon has grown to be quite round. It is all bright and it is round. That is what is called a "full" moon. You can see the full moon rising in the east, just as the sun is setting in the west, once in every month. In the sixth picture the moon is of an oval shape, not round, and only part of it is bright. In the seventh there is a half moon again, just as there was a half moon in the third picture, only the bright part is turned a different way.

And in the last picture of all there is a broad sickle (or crescent), like the crescent in the second picture, only it is turned another way.

What is the meaning of all these pictures? It is such a pity that we have to study the moon from pictures, you and I. It would be so much more simple if we could go together out into the night and *look* at the moon ourselves.

But if we can not do this together, you can do a great deal of study by yourself. It will only take a little time every night for you to make a drawing of the way the moon looks (that is, if the night is clear and you can see the moon at all).

It will be a very useful thing if you can do this. And it will be quite interesting too. Let me tell you how you can do it in the best way. You must get a little blank book, and it will be a good plan for you to borrow a silver half dollar from your father. The book is to make your drawings in, and the half dollar is to make circles with.

In the first place, what is it you want to learn by making these drawings? You know already that the moon is sometimes a full circle, and that sometimes it is a crescent—a sickle; but you can not tell me, now, exactly when these changes happen, nor exactly why they happen, so that you need to make these little drawings day after day to find out *when* the changes come. After you know when they come, perhaps we can find out *why* they come. At any rate, your drawings will tell you when they come, and so much will be gained.

Suppose you make one drawing of the shape of the moon every day that you can; and suppose your little book has fifty or sixty pages in it. Some days it will be cloudy, and you can not see the moon at all. There will be no drawings for those days, of course. And on some days the moon will rise in the east after you have gone to bed, and when you are fast asleep. So on those days, too, there will be no drawings. Never mind. You are only asked to do the best you can.

Just remember to look for the moon in the sky every night and every day. If you see it you must draw the shape of it. You need not draw anything except its shape. Do not try, at first, to draw anything but the lines that are round the bright part of the moon; not any spots or dark places on it. Just the shape. We are trying now to find out why its shape changes.

Suppose you begin in *this* way. You go out of doors and look round in the sky for the moon. Sometimes you can not find it at all. Sometimes you will see it in the night-time.

Sometimes you will see it in the daytime. Very well. All you have to do is to put down in your little book just what you see. If you see nothing at all you are to put that down, too.

Every leaf of your little book belongs to a day. One leaf for every day. Suppose that you see the moon on Tuesday, the 1st of March, at six o'clock in the afternoon. Look carefully at the shape of the moon. Is it round or is it sickle-shaped? Which way do the two horns of the sickle (the crescent) point—towards the sun or away from the sun? If the sun has set you can at least tell whether the horns point eastward or westward.

Now, have you made up your mind which way the horns point? Have you made up your mind what the shape of the moon is to-day? If you have, you can begin to make your first drawing. Begin by laying the half dollar down on the middle of the first page, and take a sharp pencil and make a whole circle with it all round the half dollar.

You must hold the book open before you. You must always face toward the south. The right hand side of the page will be toward the west. Put a W there, then, to stand for west. The left hand side of your page will be toward the east, so put an E there to stand for east. And you had better write top and bottom too, as in the picture.

You are ready to draw in the shape of the moon so soon as you have made up your mind what the shape really is. Look hard and *see* what the shape is and remember it, and then draw it in this way.

That is, you are to draw the line inside the circle you made at first, so that the shape is as near the shape of the moon as you can make it. Suppose it is like this figure. Then if you can *see* the sun, or if you know by the light of the sky pretty nearly where the sun is, you can draw an arrow which points from the moon towards the sun. If you do not know where the sun is, leave out the arrow.

Now you have finished the drawing; but a drawing of this sort is not of much use until it has a date to it. You must write on the page *first*, the year—if it is 1898, write it down. Then you must write the day of the week—if it is Tuesday, write that. Next you must write the day of the month—as March 1st. And then you are to write down the time of day—as six P. M. (six in the afternoon) or whatever the hour is. You can take the time from a watch, and you need only to write down the hour. Never mind the minutes now.

When all this has been done, there is one more thing to do. You must write your initials at the bottom of the page. You must sign it. Write down F. D., if those are your initials. This means that you have made the best drawing that you can; that it is right so far as you know; and that you are responsible for it. Every good drawing should be signed. And if your first drawing is not good, you must make another one that is good, and sign that one.

So, every day you can make a drawing, the best drawing possible. And you must remember to put in the year, and the day of the week; the month and the day of the month; the hour of the day (this tells whether it is daylight or dark, you know); and finally you should sign the page. And always recollect to face the south when you are making the sketch.

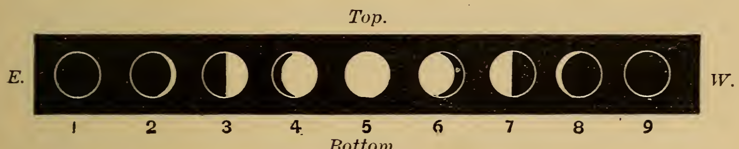
On some days the sky will be cloudy and you can not see the moon. Use a page of your book for this day just the same, and write, "*Cloudy*—no moon seen," and sign the page. And on some days it will be clear weather and yet no moon can be seen while you are awake. You should take a page of your book for such days too, and write, "*Fair*—no moon seen," and sign that.

But whenever the moon is to be seen during the hours that you are awake, either in the daytime or at night, you should make a drawing of its shape as well as you can; and you should write down the year and month, and day of the month, and day of the week, and the hour, and sign the page. Signing it means, "I have done the best I can, and the page is right as nearly as I can make it."

You must not mind, Master Frank, if your drawings are not exactly right at first. All you have to try for is to make them as nearly right as you can. That is all anybody can do—to do as well as he can; to take pains; to be patient about it.

Finally, you will have your book filled. Some of the pages will have no drawings, because the night (or day) was cloudy. Some of the pages will have no drawings, although the night (or day) was fair. Very likely Master Frank was sound asleep when the moon was overhead, shining. But you will have a number of drawings, anyway. And each one of them will give the shape of the moon as well as you can draw it.

It has taken a good many days—fifty or sixty—but you have done the best you knew how to do, and you have a number of drawings of the shape of the moon. That is, of the shape the moon had on those particular days.



The bright part of the moon goes through changes like these every month. You first see it as a new moon in the west about sunset like No. 2. It is full moon when the shape is like No. 5, and so on.

If you have been successful you may have a number of drawings like Nos. 2, 3, 4, 5, 6, 7, 8, in the picture. Never mind about Nos. 1 and 9. Forget them just at this minute and let us think about the others.

You will have, perhaps, a drawing like No. 2. The horns of the crescent are turned away from where the sun was. The drawing was made sometime near sunset. The moon was a *new* moon, as we say. About four, five, or six days later than this drawing you will probably have a drawing in which the moon looks something like the moon in No. 3 of the picture. It is a half moon. There may be a drawing like No. 4 three or four days after the day of the half moon.

You must be careful not to mistake a moon like No. 4 for a moon of the shape of No. 6. There is a difference, you see. The bright part of No. 4 is toward the *west*. The round part of No. 6 is toward the *east*. Be careful not to mistake a moon like No. 3 for a moon like No. 7. The bright half of the moon in No. 3 is turned toward the west. The moon in No. 7 has its bright half turned away from the west. Very likely you may not see a moon of the shape of No. 7 at all. If you do see it you will see it very late at night, or else in the daytime and in the west, after you have had your breakfast probably.

Sometime, if the weather is fair, you will see a full moon like No. 5. It will be of this shape about a week after the half moon of No. 3, and about a week before the half moon of

No. 7. Talking about these pictures is not nearly so good as really seeing the moon in the sky, and talking about the real moon. But it is the best we can do; and if you have made a good set of drawings we shall understand each other at any rate.

Well, you have arranged all your drawings in order and you have a set of pictures like the last figure, or like the eight pictures in one group of the picture on page 50. (Turn back and look at it, please.)

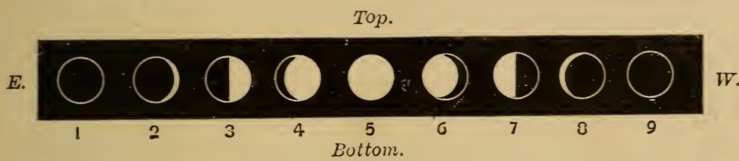
You know now that the moon changes its shape from night to night. You knew that before, but you know it better now, for you have taken pains to know. And you know pretty well when it changes. That is, how many days it takes to change from one shape to the next one. That much you know for yourself. The next thing is to try to find out why all this happens.

CHAPTER VII.

WHY THE BRIGHT PART OF THE MOON CHANGES ITS SHAPE FROM NIGHT TO NIGHT.

SEE if you can find among the drawings you made of the shape of the moon two that are alike. If you can, you will find that one was made just about a month later than the other. If the moon was "full" on April 10th (for example) it will be "full" again about May 10th, a month later. Every month there is a full moon and the next full moon comes a month later (to be exact, it comes twenty-nine days later). In fact, the month was invented ages and ages ago, by the men of early times, so that it should be just long enough to take in the changes of the moon.

At the beginning of a "lunar" month (a moon month) there is no moon to be seen at all. It is just before "new" moon. (Look at No. 1 in this set of nine pictures.) The very first sight of the "new" moon (No. 2) comes



about sunset. The sun is just setting, or has just set, and you see the faint crescent moon in the western sky. Its round part is turned toward the sun, and its two sharp horns are turned away from it.

The bright crescent grows wider and wider and a few days later you will see that the shape of the moon is just half a circle (No. 3). Then the circle changes into an oval like No. 4, and finally into a full circle like No. 5. This is the "full" moon and it comes about fifteen days after the beginning of the "lunar" month, or about twelve or thirteen days after the day on which the "new" moon is first seen.

The full moon always rises in the east just about the time that the sun is setting in the west. They are opposite to each other, and the sun is shining full on the face of the moon, and we are seeing the whole of the face that is shined upon. After full moon the shape changes, as you know. The "old" moon gets to be oval again, like No. 6, and then it gets to be a half moon once more of the shape shown in No. 7. Only *this* half moon has its round side turned to the eastward. The other half moon that came soon after new moon (No. 3) had *its* round side turned toward the westward.

By and by, in the late night or early morning, you can see the moon a sickle again—a crescent—like No. 8. And this sickle will have its round side turned eastward. The "new" moon (No. 2) had *its* round side turned westward. The round side is always turned toward the place where the sun is. The sun is shining on the moon on that side and is making it bright.

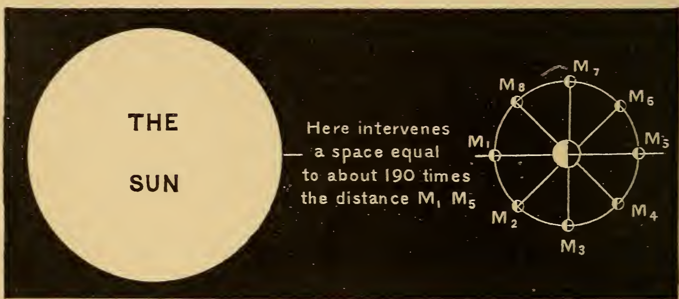
Month after month these things happen, and the moon's shape changes. Twenty-nine days after one new moon comes the next new moon. Twenty-nine days after a full moon comes another full moon, and so on forever. It has always been so as long as men can remember; and it will always be so for ages to come.

The reasons for these changes are not very, very hard to understand though they are not really easy. You must remember four things that I am going to tell you. In the first place, the moon does not shine by its own light. It is just a globe of rocks which the sun shines upon. The half of this globe which is turned toward the sun is lighted up—is bright.

In the second place, the moon moves round the earth in a circle, far away from us, but always at the same distance. In the third place, it takes the moon twenty-nine days to go once round the circle. It starts from a point in the circle and it moves round the earth, and twenty-nine days later it comes back to the point it started from. It doesn't stop there, of course, but keeps right on, and in another twenty-nine days it has gone round the circle again, and so on. The circle is not near to the earth. It is very far away.

And the fourth thing to remember is that you are on the earth watching the far-away moon in the sky, and seeing only one side of it. You are seeing the half of the moon that is turned toward you. Sometimes that half is all bright. Sometimes it is only partly bright.

Look at this picture now, Master Frank,



This picture shows why the bright part of the moon shows different shapes to us on the earth at different times of the month. The sun is at the left hand side of the picture. It is shining on the earth and the moon at the right hand side. The earth is the globe in the center of the circle, M is the moon. It shines on one half of the earth, and makes day-time. It shines on one half of the moon—on that half turned *toward the sun.* We who live on the earth can see only the half of the moon *turned toward us.* So that we see the moon of various shapes.

and see what it means. The sun is on the left of the picture and you must imagine it to be shining. It sends out sunlight and shines on everything on the earth and makes the daytime, and on the moon and makes the bright moon that we see. It is very far away.

Now, in the picture you must find the little globe in the center of the circle of Ms. That is meant to be the earth. We have to draw it very small, you know. Let us call it E.

E is the earth and one half of it is bright—the side turned toward the sun; and the other half of it is dark—the side turned away from the sun. It is daytime where the sun shines, isn't it? Well, then, the left-hand half of that little globe E, the earth, must be in the daylight; and it must be night on the right-hand half of the little globe in the picture.

Round the earth E there is a circle with eight little globes, M_1, M_2, M_3, M_4, M_5, M_6, M_7, M_8, on the circle. The circle is meant to show the path in which the moon moves round the earth, and the eight little globes are meant to show eight of the places where the moon will be in the course of a month. If the moon is at M_1 at the beginning of a month, it will move to M_2 in about three and a half days. In three and a half days more it will move to M_3, and in three and a half days more to M_4, and so on.

In just half a month—in fourteen and a half days that is—it will move halfway round the circle to M_5, and in the rest of the month it will move over the rest of the circle to M_1. Just a month after it left M_1 the moon will get back to M_1 again, and so on. Now let us look at one of the little globes on the circle. Let us begin with M_1.

You see that this little globe, M_1, has one half bright and one half dark. The half that is turned toward the sun is bright. It is day-time on that half of the moon, and it is night-time on the other half of that moon M_1, because the sun is not shining on that half.

The daytime side of the moon M_1 is turned toward the sun. The night-time half of the moon M_1 is turned toward the earth; and the people on the earth, you among them, can not see the moon, of course. There is nothing to see it by. All the sunlight is on the other side—on the farther side—on the side turned away from you. The moon is not seen by people on the earth when it is on a line from the earth toward the sun.

Now let us look at another of the little globes in the picture. Let us take M_3, the picture at the bottom of the circle. The sun is shining on the left-hand half of the globe of the moon at M_3, and making that left-hand half bright. The right-hand half will be dark, of course, because the sun does not shine upon it. Now how will the moon at M_3 look to you? Recollect that you are a little speck on the earth at E, and that you are looking out toward the moon in the sky at M_3. You are looking along the line E to M_3; from E toward M_3. If you look along any other line you will not see the moon, because the moon is at M_3 and nowhere else.

The left-hand half of the moon at M_3 is bright, and the right-hand half of the moon is dark. How will it look to you? Imagine yourself standing up on E—the earth—and looking at M_3. Your back will be turned to the top of the page and you will be looking downward on the page along the line from E to the moon at M_3. You will see the moon half bright like No. 3 in the picture on page 63. The bright half of the moon will be on the right-hand side and the left-hand side will be dark.

Now let us look at another one of the little globes. Take M_5 this time. The sun is shining on the left-hand half of M_5 and making it bright. (The sun shines below the earth at E. It shines past it. The earth is not really placed so as to stop the sun's light, though the last picture has to be drawn as if it were so.)

The sun lights up the left-hand half of the moon at M_5 and makes it bright; and you are standing on the earth at E, looking at the moon at M_5, along the line from E toward M_5. This time your back is toward the sun, your face is toward M_5, and your eyes are looking along the line from E to M_5. The half of the moon that is turned toward the earth—toward you—is all bright. Therefore you will see the moon all bright—full moon—as in No. 5 of the picture on page 63. When you stand on the earth, with your back to the sun, and see the moon just opposite to you, it will be a full moon.

Now you must study the last two pictures for yourself carefully, Master Frank. You may better take a pin for a pointer and study each one of the little globes by itself, just as we have studied the moon at the two places M_3 and M_5.

Put the pin on the earth at E in the picture. You are standing *there*, looking out at the moon in the sky. When you look out along the line from E to M_2, for instance, what do you see? The left-hand half of the moon at M_2 is shined upon by the sun. The right-hand half is dark. As you look you will see the shape of the moon like No. 2 in the last picture but one.

If you look along the line from E to M_4 you will see the moon like No. 4; if you look along the line from E to M_5, it will be like No. 5, and so on. You may better try each one of the different places, M_6, M_7, M_8, and you will see that the moon in those places will look like Nos. 6, 7, and 8 in the last picture.

Now you can see *why* it is that the bright part of the moon changes its shape from night to night. The real moon is always of the same shape, of course. It is a globe. The sun shines upon it and lights one half of it only. It lights the half that is turned toward the sun, of course. You are standing on the earth, and when you are looking at the moon you see it sometimes of one shape and sometimes of another.

Sometimes the bright part of the moon is a crescent—a new moon. That is because you are looking toward the sun. You can not see the whole of that part of the moon that the sun shines upon. Sometimes the bright part of the moon is quite round—a full moon. That is because you are looking away from the sun and because you are looking at exactly the same half of the moon that is lighted up by the sun. The sun lights all of one half, and at full moon you see all of that half. The sun always lights one half. But you sometimes can not see the whole of the lighted half, but only a part of it.

You, of course, are always on the earth, and nearly always in the same place—in the same city. But the moon does not stay in the same place. It moves round the earth in a circle (it is about a half million miles across that circle).

Do you understand now why it is that the bright part of the moon has different shapes at different times? I hope you do, and I think that you do. But if it is a little too hard to understand you may better go on and read the next chapter of this book about the stars. And afterward you can read *this* chapter over again very carefully, and perhaps you can get some older person to read it with you. Of course it takes trouble to understand any science like astronomy. The world is not simple. But if you take pains, and go slowly, and have patience, you can understand very much. There is no hurry anyway, is there? There is plenty of time; and you have got all the time there is.

CHAPTER VIII.

THE STARS IN THEIR COURSES—THE EARTH TURNS ROUND ONCE IN EVERY DAY.

All the day the sun is shining and making daylight. By and by comes sunset and the sun has gone below the horizon—below the rim of the world—in the west. He leaves the clouds and the sky bright and you can see only a very few stars—only the brighter ones.

The sky now begins to get darker and darker, and little stars begin to peep out here and there. In an hour or less after the sun is set the whole sky is quite dark (unless, perhaps, the bright moon is there) and you can see hundreds and hundreds of stars. The sky is full of them. Some of them are very bright indeed, some are much fainter, and some you can scarcely see at all. But they are there—little, bright, twinkling points.

We could not see the stars in the daytime, an hour before sunset, for example, because the sun's light was so bright. The daylight made the whole sky so bright that the stars, which were there all the time, couldn't be seen. The stars *are* in the sky all the time. We do not see them in the daytime simply because the sky is so bright that the strong daylight blots out the feeble light of the stars.

Make a little dot of ink on a piece of paper. Now take the end of a match and make a blot over the little dot. The dot can not be seen any more. But it is there all the time, under the blot. Just in the same way the light of the day blots out the light of a star.

We know for certain that the stars are there, shining in the daytime, though your eye can not see them, because astronomers can see them in their telescopes. They can see them, and they often and often do see them, and if you could look into their telescopes you could see the stars in the daytime too.

As the sun sets the sky gets darker. Only the very brightest stars can be seen just then. Such stars must be brighter than the sky in order that you may see them at all. And so, of course, the brighter stars will be the first to be seen after sunset. And the farther away from the sun you are looking just after sunset, the more stars you will see. Because, of course, the sky is darker farther away from the sun, and a star that will show plainly on this dark sky may be too faint to be seen close to the sun.

All the stars, you know, shine by their own light, just as the sun shines by his own light. They are not like the moon which has no light of its own, but they are like the sun; and each one of them shines by its own light. If you could hide the sun's light all the stars would go on shining just the same; but if the sun's light was really hidden—if the sun was blown out like a candle—the moon would never shine again.

All the moon's light comes from the sun. Each star has a light of its own. If you want the stars put out, you must put them out one by one like separate candles. If you want the moon put out you can only have it by blowing out the sun.

When you are looking up at all the stars in the dark sky what do they look like? They appear like bright shining sparks fastened on to the inside of a huge hollow half globe. We are standing in the middle of this globe on the solid earth. All round us and above us is the immense globe of the sky, like a huge basin.

Look off to the north, or to the east, or to the south, or to the west; in every direction you can see that the bowl of the sky is very large indeed. It seems to come down and meet the ground all around the horizon. Lie down on your back and look straight overhead, and you can look on and on, ever so far; but by and by you seem to come to an end, and you seem to have reached the hollow bowl of the sky. In every direction you will find the same thing. In every direction there seems to be a huge bowl above us and around us.

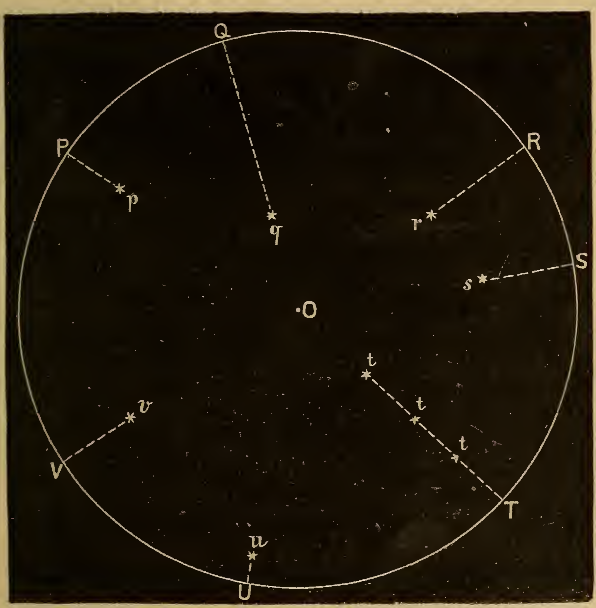
On the inside surface of the bowl the stars seem to be fastened like little shining sparks—some bright, some fainter. So, when you think of it, the stars seem to be—they appear to be—all at the same distance from you. They all *seem* to be fastened on the inside of the great hollow bowl.

But the stars are not all at the same distance from you by any means. Far from it. All of them are very far away indeed. All of them are much farther away from you than the moon is, or than the sun. But some of the stars are ten times farther off from you than the nearest stars. Some are a hundred and others a thousand times farther off from you than these nearest stars.

If this is so—and I will some day prove to you that it is so—then it is plain that all of the stars can not be fastened on the inside surface of a great bowl. They certainly look as if they were fastened that way. But they can not be so fastened. No one bowl would do. The near stars and the farther stars could not be fastened to the same bowl.

So that it is not a true appearance, this bowl of the sky. It looks as if there were such a bowl, on which all the stars are fastened. But there certainly is no such bowl. It is all a mere appearance. Let us see how it happens to look like that.

Here is a picture, and in the middle of it is a white dot marked *O*. That white dot is

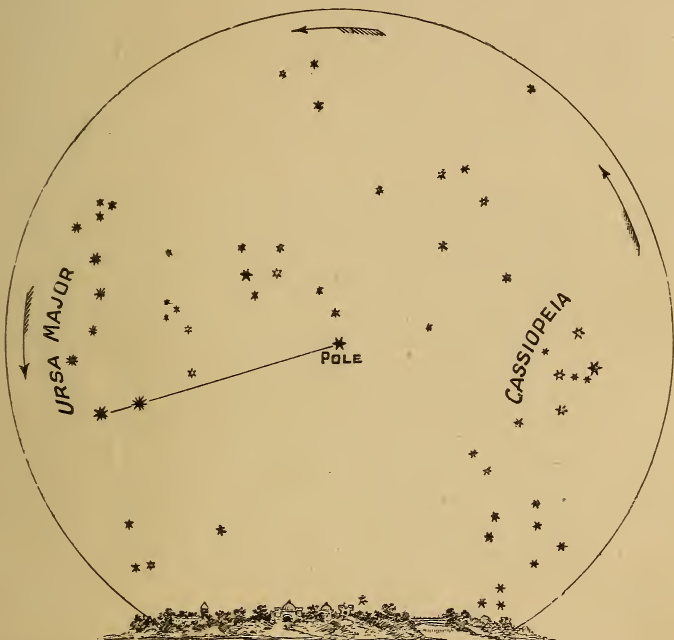


supposed to be the earth, and you are on it, looking out at the stars in the dark night. *p*, *q*, *r*, *s*, *t*, *t*, *t*, *u*, *v* are stars at different distances from you. The star *p* is farther away from *O* than the star *q*.

If you look at the star *p* from *O* you look along the line *O p P*, and you seem to see the star *p* at the place *P* on the inside of the hollow bowl. If you look at the star *q* you look along the line *O q Q*, and you seem to see the star *q* at *Q* on the inside of the hollow bowl. If you look at the stars *r*, *s*, *u*, *v*, along the lines *O r R*, *O s S*, *O u U*, *O v V*, you seem to see them on the hollow bowl at *R*, *S*, *U*, *V*.

Suppose there were really three stars, *t*, *t*, *t*, at different distances from you, but all in one line. You would only see one star. It would seem to be on the inside of the hollow sky at *T*. The white circle in the picture is meant to show what we have called the inside surface of the hollow bowl of the sky.

It seems to have stars sprinkled all over it at *P*, *Q*, *R*, *S*, *T*, *U*, *V*, and at other places; and all these stars seem to be at the same distance from you. *P* is just as far from *O* as *Q* is, as *R* is, etc. But the stars are really at different distances from you. Some of them are near, like *q*, and some of them are far off, like *u* and *v*. They simply appear to be on



This picture shows the stars in the northern part of the sky as they look in the early evening in midsummer. All of the stars move round the sky from east to west—from rising to setting—once every day. The Pole Star alone stands still. The Great Dipper (marked *Ursa Major* in the picture) moves. Two of its stars, the Pointers, always point to the Pole Star.

the hollow sky, and the hollow sky itself is nothing but an appearance. Remember that.

Here is a picture of a part of the sky,

Master Frank, from which you can learn other new things. No one picture can show the whole sky; nor can any one picture do more than to show a part of the sky at some particular month and day and hour. The stars rise and set like the sun and moon, you know. A picture will only serve to show the stars as they are at some particular hour after they have risen, and before they have set. If we want a view of them at some other hour we must make another drawing.

This picture is drawn to show the stars in the northern sky as they stand in the early night-time in every August. If you compare it with the stars in the sky in some other month it will not agree exactly, but it will not be hard for you to find the groups of stars at almost any time. The very first group of stars to find is the great Dipper. (See page 83.)

Here is another picture which shows eight stars. Seven of them make the Dipper, and the other one is the pole-star. It is at the north pole of the sky, and it has a special name, which you must fix in your memory.

Its name is *Polaris*. *Polaris* is the pole-star, or the north star. The stars of the Dipper are part of a group that is called the *Great Bear* (*Ursa Major* in Latin), and they are named by Greek letters, as in the picture. But you need not learn the Greek letters. They are

Ursa Major and Polaris.

the first seven letters of the Greek alphabet:

$\alpha \; \beta \; \gamma \; \delta \; \epsilon \; \zeta \; \eta$

You can find the seven stars of this picture in the picture that is printed on page 81. They are on the left-hand side of that picture. You can easily find them in the sky on any clear night. They are pretty bright; they are in the north somewhere, and they are almost always to be seen if the sky is clear.

In the northern parts of the United States they are rather high up in the sky. As you go farther south they get to be lower in the heavens, but you can always see the two *Pointers*, α and β, in Virginia and in North Carolina, and in all the States as far north as these. These two stars—the two *Pointers*—have a line drawn through them in both pictures. The line drawn through them points to *Polaris*, the pole-star, and they get their name for that reason.

The line through the Pointers *always* points to *Polaris*. In the last picture the two Pointers are just below *Polaris*, and the line points upward. In the larger picture the line of the two Pointers is shown pointing to the right (as it does in August).

No matter what the time of year, or month, or day, may be, no matter what o'clock it may be, the line through the two Pointers points to the pole-star, *Polaris*. Every time you go out of doors on a clear night you can see that this is so. And you may better get into the habit of glancing up at the northern sky to notice this. It is always so, and you can prove it at any and every time you wish.

The first thing for you to do is to learn to find the Dipper quickly. Very likely you know how to do this already. At any rate, you can soon learn. There is the handle of the Dipper, made out of three stars (ϵ, ζ, η in the last picture), and there is the bowl of the Dipper, made out of four stars (α, β, γ, δ).

Two of these four stars, α and β, are the Pointers. Imagine a long line drawn through these two Pointers; this line will pass (nearly) through *Polaris*. You must learn, if you please, to find *Polaris* quickly in the sky. The moment you go out of doors at night you should see it.

The stars α and β, the two Pointers, *always* point to *Polaris*. Sometimes you will find these Pointers below the pole, pointing upward, as they are drawn in the last picture. Sometimes they are on the left-hand (west) side of *Polaris*, as in the larger picture. Sometimes they are above the pole, pointing downward.

Hold your book upside down and look at the last picture and you will see how they are then. You can see them like that in the sky, too, if you look at the right time. Sometimes the Dipper is on the right-hand side (east) of *Polaris*, and the line of the Pointers points to the west. You can see it this way also, if you look at the proper time.

The Dipper never changes its shape; its stars always keep their places, one star with another. But the Dipper, as a whole, moves round the northern sky in such a way that the Pointers always point to the pole-star. The little arrows in the larger picture show which way the Dipper (and all the other stars) move. Look at the picture carefully and remember that it shows exactly what happens in the sky.

Everything that we say about the picture can be proved to be true by going out of doors at night and by watching the stars. And you should do this, of course. You will never be truly certain that these stars do actually move until you have seen them do it.

Pictures with arrows in them *explain* matters, but the pictures do not prove them. It is the other way, the stars prove the pictures.

If you watch the northern stars you will find that they actually do move around *Polaris*, the pole-star, in the direction of the arrows drawn in the picture. The stars above *Polaris*, those higher up, move from your right hand toward your left hand—they move from east toward west. The stars below *Polaris* move from left to right—from west to east.

The eastern stars move upward, the western stars move downward. In the larger picture the group of stars marked *Cassiopeia* (the lady in the chair) move upward. The group marked *Ursa Major* (the Great Bear) move downward, and each of the other stars moves in a large circle around *Polaris*. *Polaris* stands still and is the center of all the circles.

Take the Pointer that is nearest to *Polaris*—for example, the Pointer (α). It moves in a circle round the pole-star and always keeps at the same distance from it. The other

Pointer (β) moves in the same way, but in a different circle. The nearest Pointer always keeps at its distance, a to *Polaris*, and the other Pointer always keeps at its distance, β to *Polaris*. But both stars are continually moving around the pole in the direction marked by the little arrows.

Here is something that you ought to recollect, Master Frank. The distance of a star from *Polaris* is called the *polar-distance* of that star. Two things are true for each and every star: 1. Each star always has one and the same polar distance. 2. Each and every northern star moves in a circle around *Polaris*. *Polaris* is the center of the circle of each star.

If you open this book to page 81, where the larger picture is, and hold it up before you, you can show how all the stars move by turning the book and the page slowly round and round while you keep the middle of the page—where *Polaris* is drawn—perfectly still.

Polaris stands still in the sky; and therefore we must keep it still in our experiment. The other stars all move about it in circles in the sky, just as we can make them move by turning the page round and round. While you are doing this you should stand up and you should face to the north, and it will be better to hold the book off at arm's length.

In trying this experiment you have shown that all the stars move about *Polaris* in the same time. It takes just the same time for a star distant from the pole to go around its circle, as it takes for a star near to the pole to go quite around *its* circle. The distant star has to move faster, of course, in order to keep up.

Now the question is, How long does it take for each star to move completely round the pole? The answer is that it takes just one day. In the picture on page 83 the two Pointers, α and β, are just below the pole-star. Suppose they are like that at ten o'clock on Monday night. If you look at them at ten o'clock on Tuesday night you will find that they are in this same place again.

It has taken them a day to move once round the pole-star, and they were moving all the time. They did not stand still for that day, but they moved. You can prove this by watching them. They will seem to move slowly enough, but they do move. We can now say another true thing about all the northern stars. Every star moves around the pole in a day.

Long ago everybody believed that the stars were bright sparks set in a crystal globe—the hollow bowl of the sky. They noticed that all the stars moved round the north star (*Polaris*, the north star, the pole-star) in a day. So they explained this motion by supposing that the crystal globe turned round once every day, carrying all its little sparks of stars round with it. They supposed that the earth stood quite still, and that the heavens, the crystal globe with the stars, turned round.

This was a good enough explanation until other men found out that there could not possibly be a crystal globe studded with stars all at the same distance. It was found out that the stars were not all at the same distance; on the other hand, that they were at very different distances. Therefore there could not possibly be one single crystal globe for all the stars.

Each one of the hundreds of stars would need to have a globe of its own. As it was not at all likely that there were as many crystal globes as there were stars, men began to look for another explanation. They wanted a simpler explanation. They found it by supposing that the stars did not move at all, but that the earth itself—this solid earth—turned round underneath the stars.

Things would *look* the same, you see, in either case. The stars would *seem* to move just the same either way. If all the stars were set in one crystal globe that turned they might all move round with it once a day while the earth stood still. Or, on the other hand, the stars might stand still in the sky and the earth might move round and round and round underneath the stars. This last explanation is the true one. The stars are still. They really remain in one place. But the solid earth moves round and round and we move with it. So that the stars seem to move.

All this time we have been speaking about the northern stars only. We can prove everything that has been said by watching them. If we should watch the southern stars what should we see? Every star in the south moves too. It rises at your left hand (you have turned round with your back to the north and your face to the south now, you know), in the east, and it moves up and across the sky till it is halfway across. It is at its highest point now, and it is exactly south of you.

Then its path leads it toward the west and slowly downward, and by and by it sets below the horizon line in the west. Every southern star does this. It, too, moves round a circle, only the lower part of *its* circle is hidden from us by the earth on which we are standing. The circles of the northern stars are high up in the sky and are not hidden by the earth. The southern stars (and the sun and the moon also) rise in the east, move across the sky, come to their highest points in the south (the sun gets to *its* highest point at noon), and decline to the west where they set.

You must watch the southern stars too, Master Frank, and prove to yourself that this is true for them also. The more you study the motions of the stars in their courses the better you will see that their motions are fully explained when we suppose one simple thing to be true.

We only need to suppose that the stars, which appear to move, really stand still, and that the earth is turning underneath them. There are many, many proofs that this is a true explanation. You can prove for yourself that it explains all the things that you see, by simply watching the stars from night to night. It is satisfying to find such a simple way of explaining so many different things, isn't it? And they are all fully explained that way.

Astronomy has many other things to explain that are much more difficult to understand. Many of these things can not be understood at all until you have learned much more. If you want to understand them you must study your arithmetic hard, and you must understand it. Then will come a kind of higher arithmetic called algebra. You have to learn that thoroughly, and geometry as well.

After these come other higher kinds of algebras and geometries; and by and by you will have learned, in the last years of your college, the things that are necessary—really necessary—for making a study of astronomy. I mean necessary for studying all parts of it.

If you wish to be able to calculate the exact time to a second when an eclipse of the sun will happen ten years from now, you must know all these arithmetics and algebras and geometries—all this mathematics, as it is called—and you must know them thoroughly. It takes time and hard work. But it is worth doing.

And if you wish to understand whether human beings can possibly live in the other planets, in *Mars*, in *Jupiter*, in *Saturn*, you will have to learn a great deal about heat, and air, and so forth and so forth. If you want to know about telescopes, you must learn all about light. The study of these things is called physics.

All the time you can be reading books about astronomical matters, and all the time you must be observing what you see going on in the sky—how the sun moves every day, how it moves in a year; how the moon moves among the stars; whether the moon is farther away than the stars or not; where the sun sets in summer, and where in winter; and a hundred other things of the same sort.

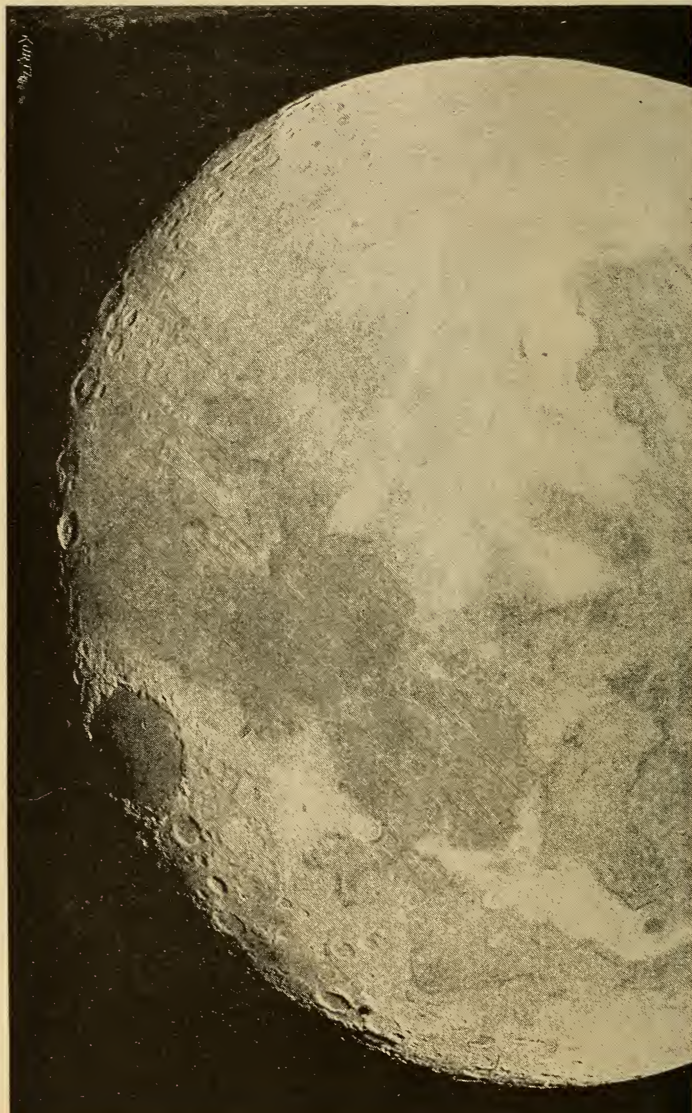
If you really wish to know the reasons for all these things, you must study physics and mathematics as well as you can, for all the time of your school, and through all the years of your college. Then you must study French and German so as to be able to read the splendid books that have been written by the great astronomers of France and Germany. And you ought to know how to read Latin too, for in old times all the wise men wrote their books in Latin.

Oh, it isn't easy, my boy; but it is worth while. And you must remember one thing: there is no hurry about it. Walking is just putting one foot in front of the other, and keeping on doing it. The boy who keeps on longest, who doesn't fret, who doesn't get impatient, goes the farthest. It is the same way with learning. Every day you have to learn *this* lesson, to put *this* foot forward. To-morrow there is another lesson to be learned, and another foot to be put in front. There is no haste, but there must not be too much rest.

By and by, if you keep on, you will get to where you wish to be. If you read this book carefully that will be a first step. And other books will be other steps. Observing what takes place in the sky itself, and thinking about it, so as to see why it takes place, will be steps that will carry you far on your way.

And you must always remember that if you want any good thing in this world you must give something. If you want love, you must give love; if you want wisdom you must give effort. Knowledge is not given away for nothing. You have to earn it by hard work and good will.

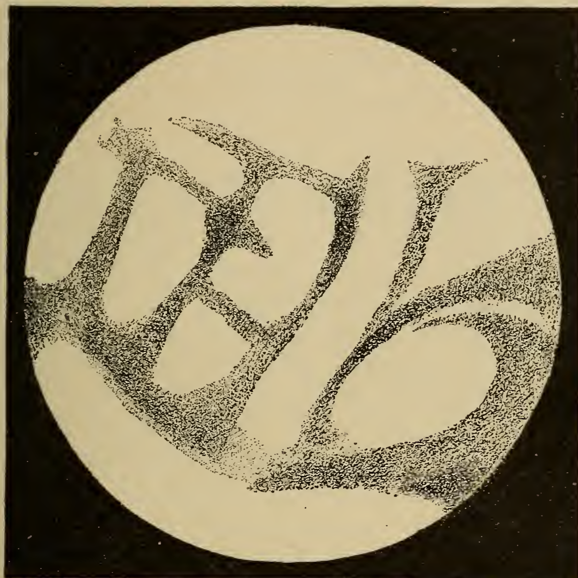
Part of a photograph of the sun, taken at the Lick Observatory.
A sun spot is shown close to the edge.



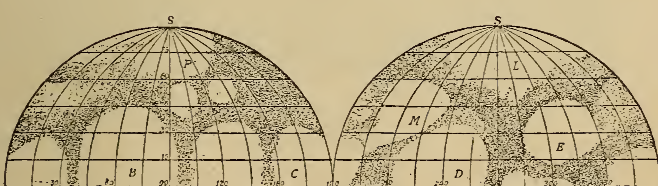
Part of a photograph of the moon, taken at the Lick Observatory. (Moon's age, 16 days 18 hours.)

Part of a photograph of the moon, taken at the Lick Observatory. (Moon's age, 8 days 1 hour.) The moon's south horn is shown.

Part of a photograph of the moon, taken at the Lick Observatory. (Moon's age, 8 days 1 hour.) The moon's north horn is shown.

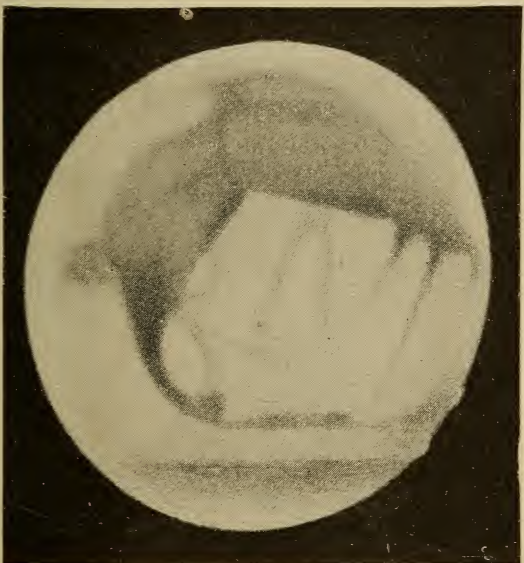


Drawing of the planet Mercury.

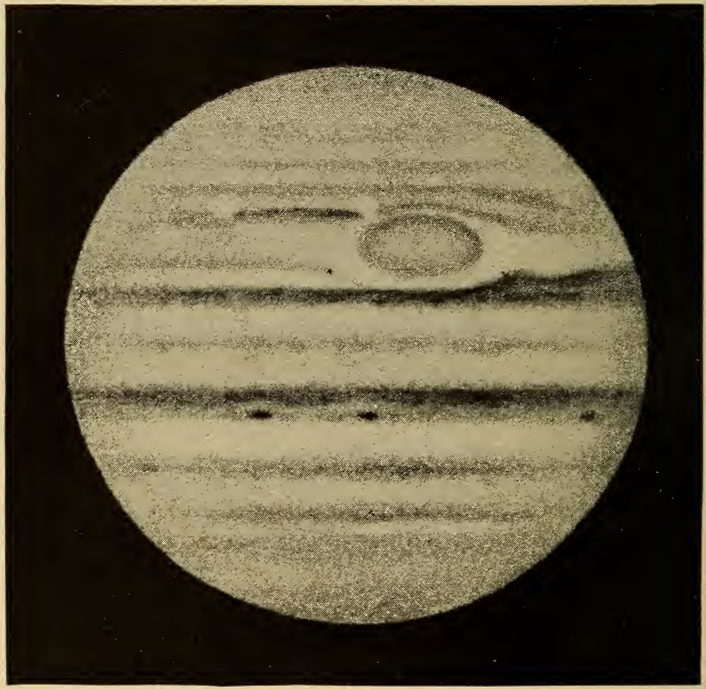


Map of the two hemispheres of the planet Venus.

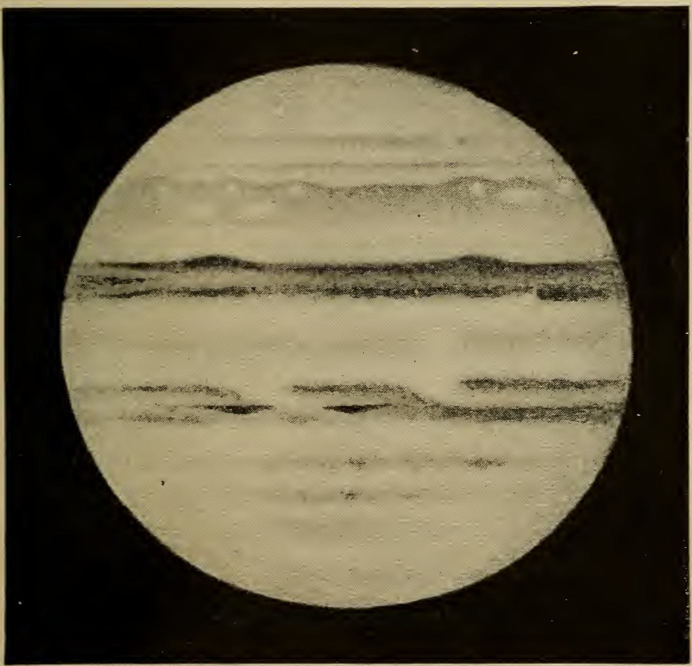
Drawing of one side of the planet Mars, made at the Lick Observatory.



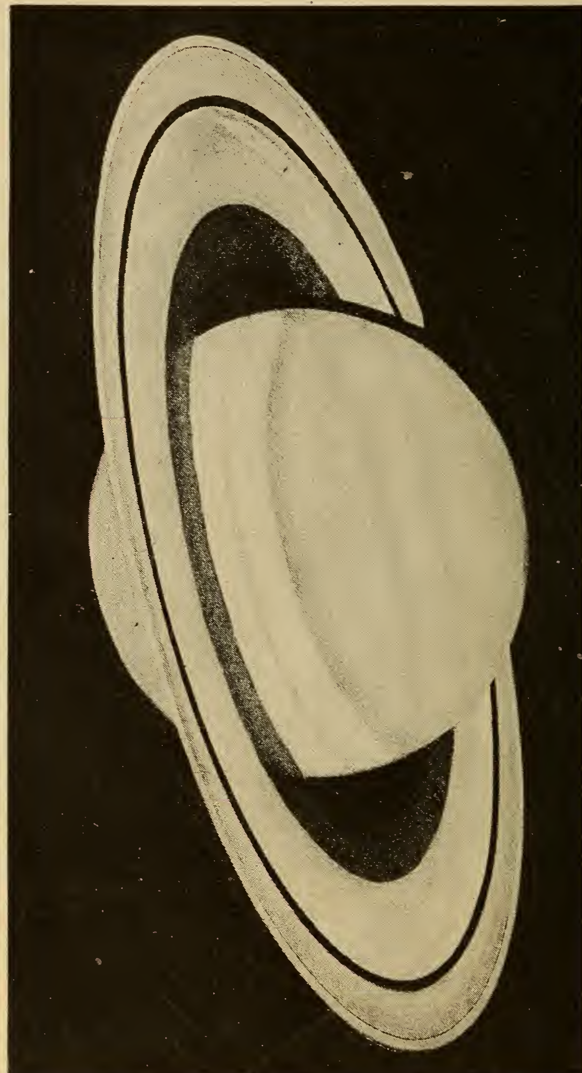
Drawing of one side of the planet Mars, made at the Lick Observatory.



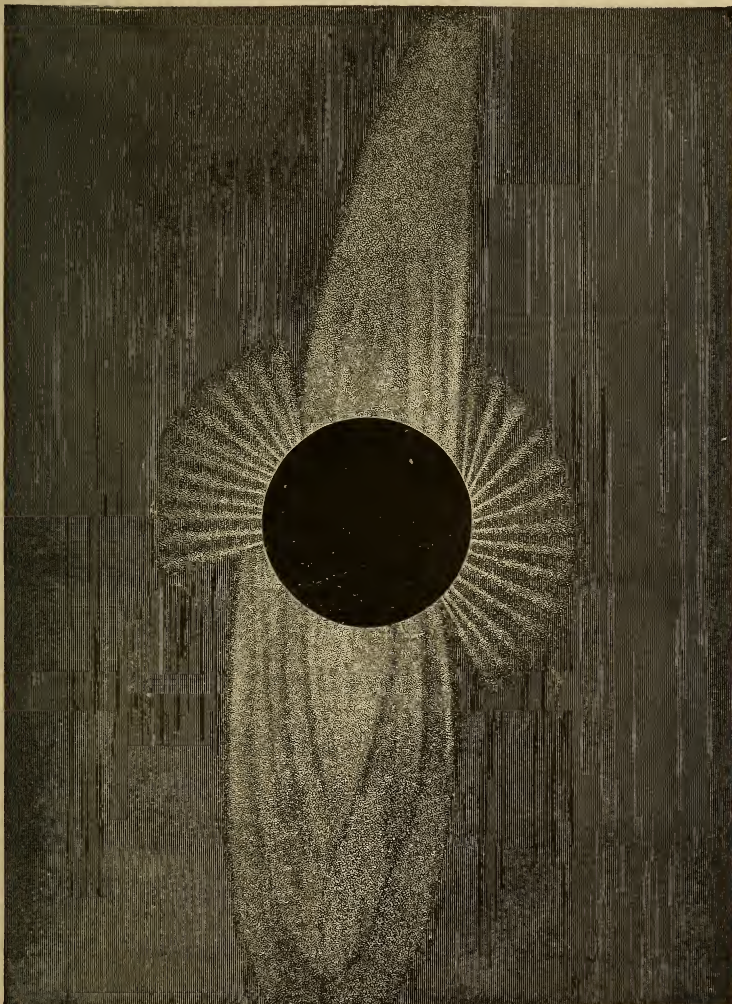
Drawing of one side of the planet Jupiter, made at the Lick Observatory.



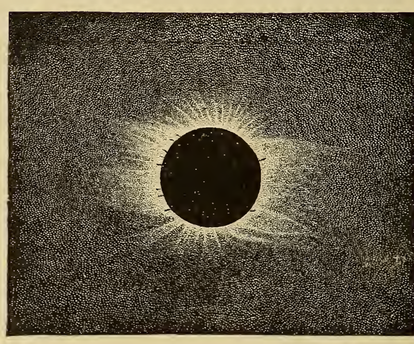
Drawing of one side of the planet Jupiter, made at the Lick Observatory.



Drawing of the planet Saturn, made at the Lick Observatory.

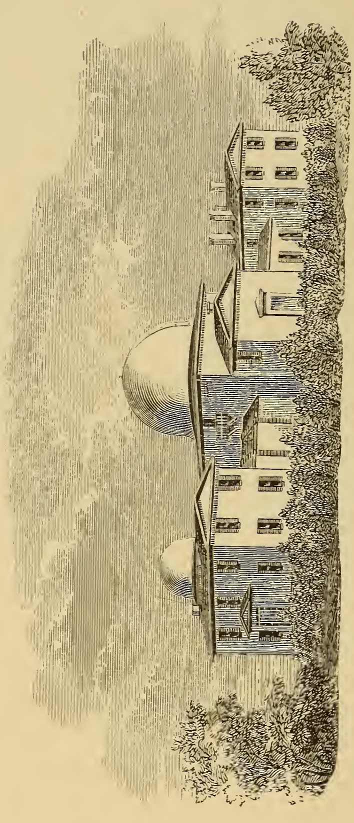


Drawing of the total solar eclipse of July, 1878, in Colorado.

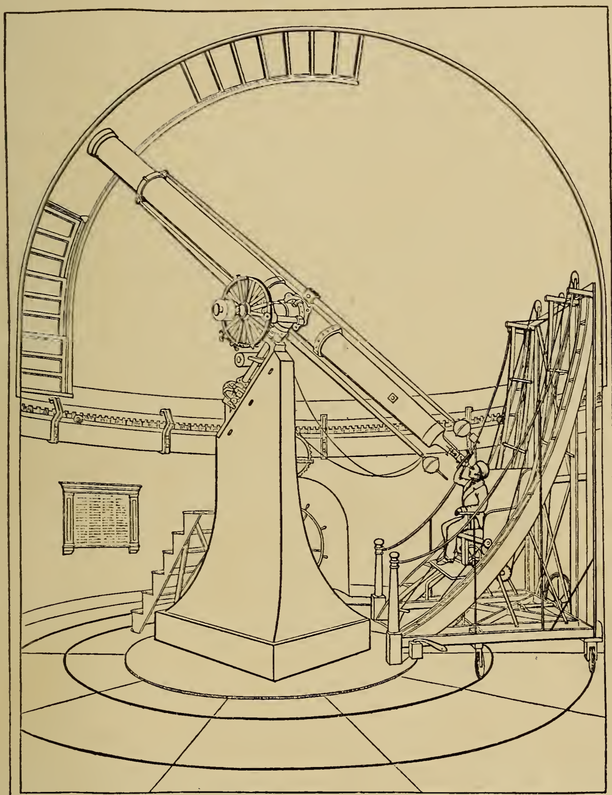


Photograph of the total solar eclipse of January, 1889, in California.

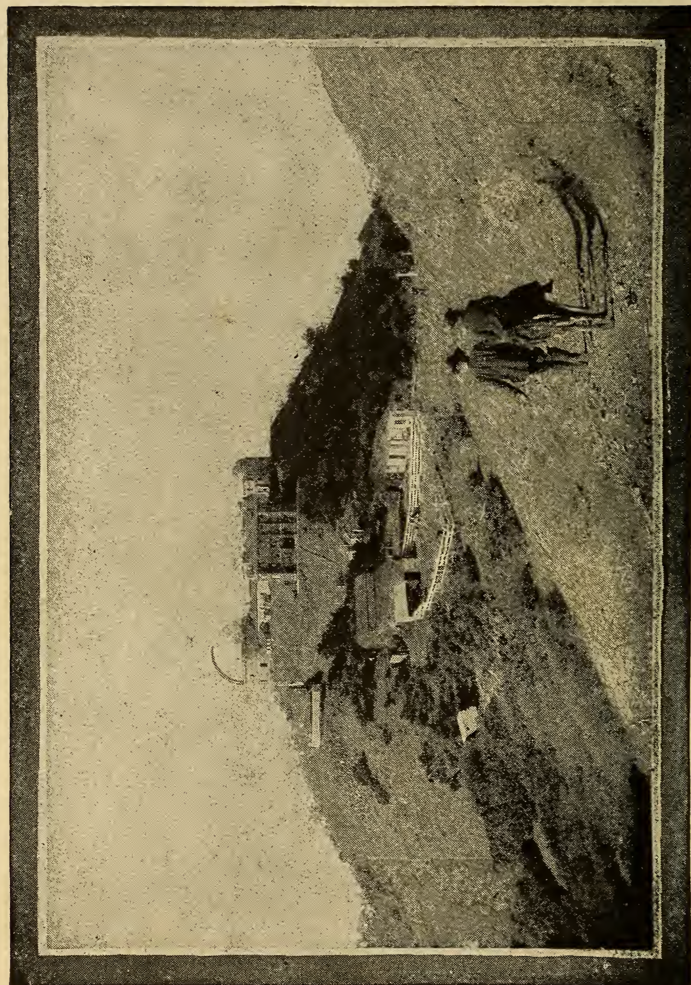
Fall of the great California meteor of 1894.



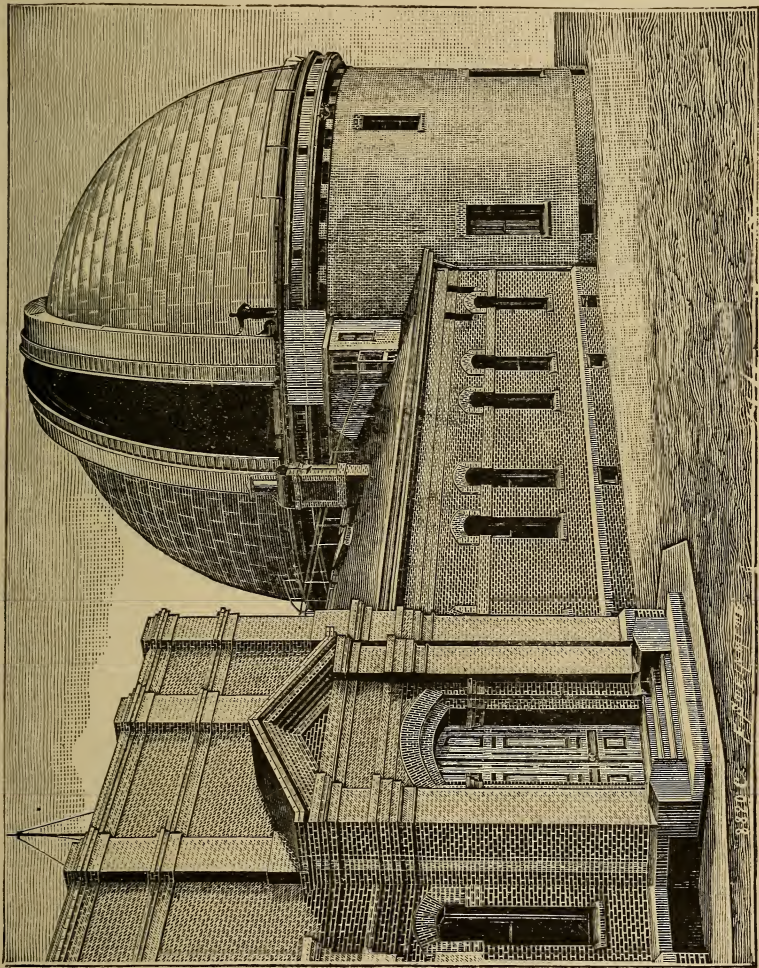
View of the observatory at Harvard College.



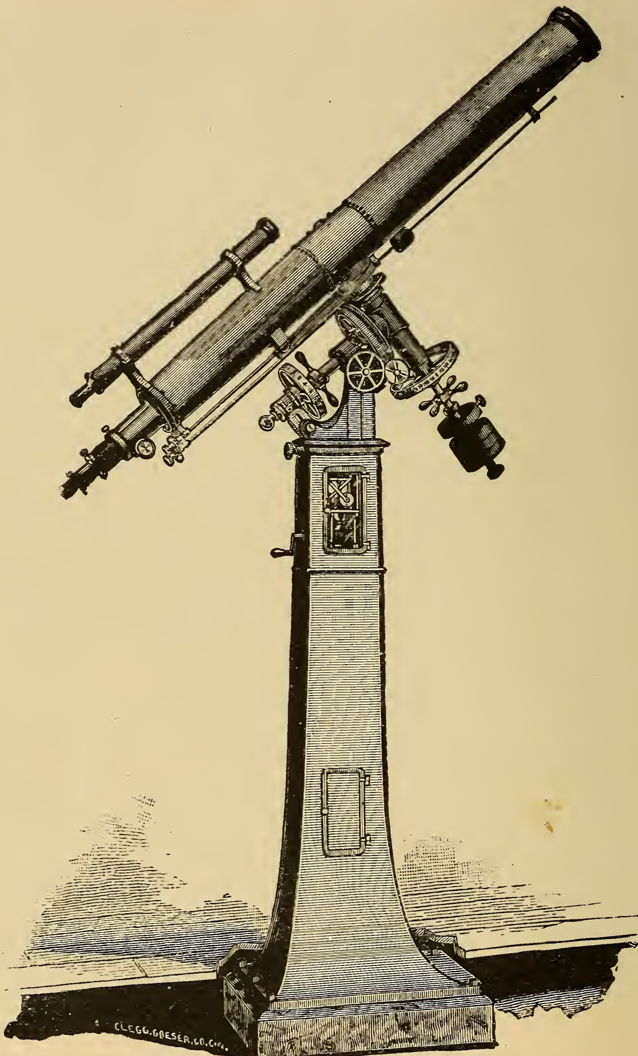
The fifteen-inch telescope of the Harvard College Observatory.
(Its glass is fifteen inches across.)



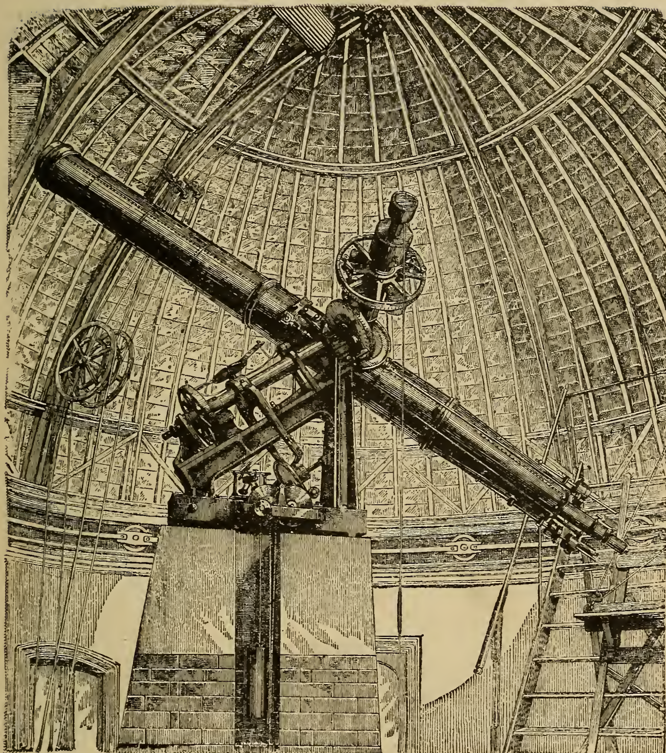
Distant view of the Lick Observatory of the University of California.



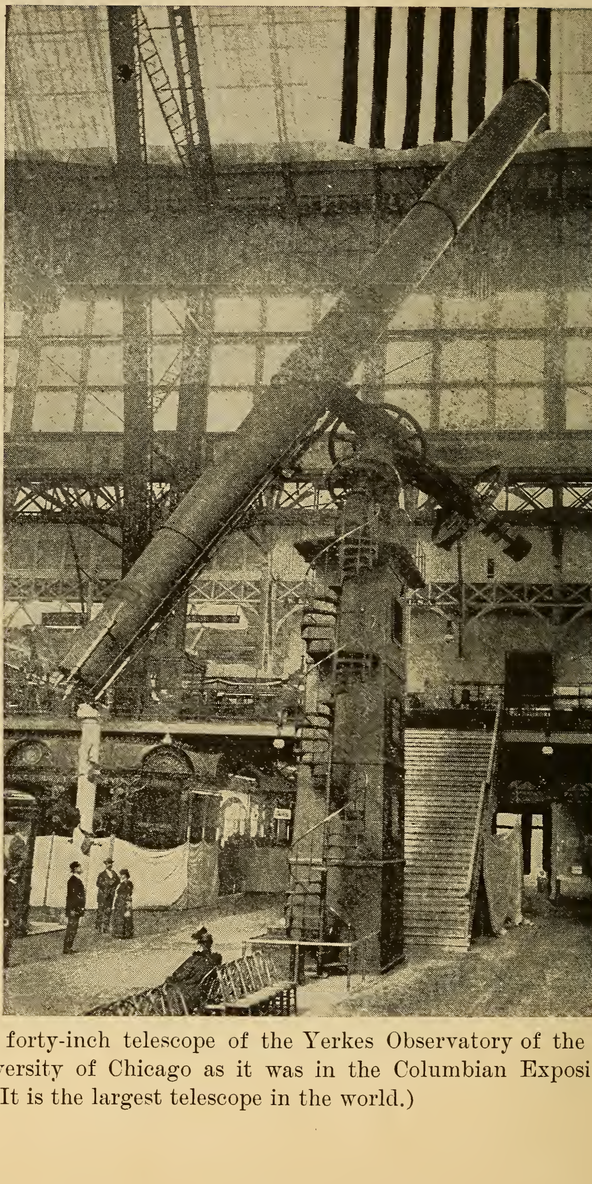
The west front of the Lick Observatory, showing the dome of the thirty-six-inch telescope.



The six-inch telescope of the Lick Observatory.



The twelve-inch telescope of the Lick Observatory.



The forty-inch telescope of the Yerkes Observatory of the University of Chicago as it was in the Columbian Exposition. (It is the largest telescope in the world.)


AFRICA