THE FAIRY-LAND OF SCIENCE

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BY

ARABELLA BUCKLEY

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PREFACE

THE Ten Lectures of which this volume is composed were delivered last spring, in St. John's Wood, to a large audience of children and their friends, and at their conclusion I was asked by many of those present to publish them for a child's reading book.

At first I hesitated, feeling that written words can never produce the same effect as *viva-voce* delivery. But the majority of my juvenile hearers were evidently so deeply interested that I am encouraged to think that the present work may be a source of pleasure to a wider circle of young people, and at the same time awaken in them a love of nature and of the study of science.

The Lectures have been entirely rewritten from the short notes used when they were delivered. With the exception of the first of the series, none of them have any pretensions to originality, their object being merely to explain well-known natural facts in simple and pleasant language. Throughout the whole book I have availed myself freely of the leading popular works on science, but have found it impossible to give special references, as nearly all the matter I have dealt with has long been the common property of scientific teachers.

ARABELLA B. BUCKLEY

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LECTURE I

HOW TO ENTER IT; HOW TO USE IT; AND HOW TO ENJOY IT

I HAVE promised to introduce you to-day to the fairy-land of science—a somewhat bold promise, seeing that most of you probably look upon science as a bundle of dry facts, while fairy-land is all that is beautiful, and full of poetry and imagination. But I thoroughly believe myself, and hope to prove to you, that science is full of beautiful pictures, of real poetry, and of wonder-working fairies; and what is more, I promise you they shall be true fairies, whom you will love just as much when you are old and grayheaded as when you are young; for you will be able to call them up whenever you wander by land or by sea, through meadow or through wood, through water or through air; and though they themselves will always remain invisible, yet you will see their wonderful poet at work everywhere around you.

Let us first see for a moment what kind of tales science has to tell, and how far they are equal to the old fairy tales we all know so well. Who does not remember the tale of the "Sleepy Beauty in the Wood," and how under the spell of the angry fairy the maiden pricked herself with the spindle and slept a hundred years? How the horses in the stall, the dogs in the court-yard, the doves on the roof, the cook who was boxing the scullery boy's ears in the kitchen, and the king and queen with all their courtiers in the hall remained spell-bound, while a thick hedge grew up all around the castle and all within was still as death. But when the hundred years had passed the valiant prince came, the thorny hedge opened before him bearing beautiful flowers; and he, entering the castle, reached the room where the princess lay, and with one sweet kiss raised her and all around her to life again.

Can science bring any tale to match this?

Tell me, is there anything in this world more busy and active than water, as it rushes along in the swift brook, or dashes over the stones, or spouts up in the fountain, or trickles down from the roof, or shakes itself into ripples on the surface of the pond as the wind blows over it? But have you never seen this water spell-bound and motionless? Look out of the window some cold frosty morning in winter, at the little brook which yesterday was flowing gently past the house, and see how still it lies, with the stones over which it was dashing now held tightly in its icy grasp. Notice the wind-ripples on the pond; they have become fixed and motionless. Look up at the roof of the house. There, instead of living doves merely charmed to sleep, we have running water caught in the very act of falling and turned into transparent icicles, decorating the eaves with a beautiful crystal fringe. On every tree and bush you will catch the water-drops napping, in the form of tiny crystals; while the fountain looks like a tree of glass with long down-hanging pointed leaves. Even the damp of your own breath lies rigid and still on the window-pane frozen into delicate patterns like fern-leaves of ice.

All this water was yesterday flowing busily, or falling drop by drop, or floating invisibly in the air; now it is all caught and spell-bound—by whom? By the enchantments of the frost-giant who holds it fast in his grip and will not let it go.

But wait awhile, the deliverer is coming. In a few weeks or days, or it may be in a few hours, the brave sun will shine down; the dull-gray, leaden sky will melt before him, as the hedge gave way before the prince in the fairy tale, and when the sun-beam gently kisses the frozen water it will be set free. Then the brook will flow rippling on again; the frost-drops will be shaken down from the trees, the icicles fall from the roof, the moisture trickle down the window-pane, and in the bright, warm sunshine all will be alive again.

Is not this a fairy tale of nature? and such as these it is which science tells.

Again, who has not heard of Catskin, who came out of a hollow tree, bringing a walnut containing three beautiful dresses—the first glowing as the sun, the second pale and beautiful as the moon, the third spangled like the star-lit sky, and each so fine and delicate that all three could be packed in a nut? But science can tell of shells so tiny that a whole group of them will lie on the point of a pin, and many thousands be packed into a walnut shell; and each one of these tiny structures is not the mere dress but the home of a living animal. It is a tiny, tiny shell-palace made of the most delicate lacework, each pattern being more beautiful than the last; and what is more, the minute creature that lives in it has built it out of the foam of the sea, though he himself is nothing more than a drop of jelly.

Lastly, anyone who has read the "Wonderful Travellers" must recollect the man whose sight was so keen that he could hit the eye of a fly sitting on a tree two miles away. But tell me, can you see gas before it is lighted, even when it is coming out of the gas-jet close to your eyes? Yet, if you learn to use that wonderful instrument the spectroscope, it will enable you to tell one kind of gas from another, even when they are both ninety-one millions of miles away on the face of the sun; nay more, it will read for you the nature of the different gases in the far distant stars, billions of miles away, and actually tell you whether you could find there any of the same metals which we have on the earth.

We might find hundreds of such fairy tales in the domain of science, but these three will serve as examples, and we must pass on to make the acquaintance of the science-fairies themselves, and see if they are as real as our old friends.

Tell me, why do you love fairly-land? what is its charm? Is it not that things happen so suddenly, so mysteriously, and without man having anything to do with it? In fairy-land, flowers blow, houses spring up like Aladdin's palace in a single night, and people are carried hundreds of miles in an instant by the touch of a fairy wand.

And then this land is not some distant country to which *we* can never hope to travel. It is here in the midst of us, only our eyes must be opened or we cannot see it. Ariel and Puck did not live in some unknown region. On the contrary, Ariel's song is

"Where the bee sucks, there suck I;
In a cowslip's bell I lie;
There I couch when owls do cry.
On the bat's back I do fly,
After summer, merrily."

The peasant falls asleep some evening in a wood, and his eyes are opened by a fairy wand, so that he sees the little goblins and imps dancing round him on the green sward, sitting on mushrooms, or in the heads of the flowers, drinking out of acorn-cups, fighting with blades of grass, and riding on grasshoppers.

So, too, the gallant knight, riding to save some poor oppressed maiden, dashes across the foaming torrent; and just in the middle, as he is being swept away, his eyes are opened, and he sees fairy water-nymphs soothing his terrified horse and guiding him gently to the opposite shore. They are close at hand, these sprites, to the simple peasant or the gallant knight, or to anyone who has the gift of the fairies and can see them. But the man who scoffs at them, and does not believe in them or care for them, he *never* sees them. Only now and then they play him an ugly trick, leading him into some treacherous bog and leaving him to get out as he may.

Now, exactly all this which is true of the fairies of our childhood is true too of the fairies of science. There are *forces* around us, and among us, which I shall ask you to allow me to call *fairies,* and these are ten thousand times more wonderful, more magical, and more beautiful in their work, than those of the old fairy tales. They, too, are invisible, and many people live and die without ever seeing them or caring to see them. These people go about with their eyes shut, either because they will not open them, or because no one has taught them how to see. They fret and worry over their own little work and their own petty troubles, and do not know how to rest and refresh themselves, by letting the fairies open their eyes and show them the calm sweet pictures of nature. They are like Peter Bell of whom Wordsworth wrote:—

> "A primrose by a river's brim
> A yellow primrose was to him,
> And it was nothing more."

But we will not be like these, we will open our eyes and ask, "What are these forces or fairies, and how can we see them?"

Just go out into the country, and sit down quietly and watch nature at work. Listen to the wind as it blows, look at the clouds rolling overhead, and waves rippling on the pond at your feet. Hearken to the brook as it flows by, watch the flower-buds opening one by one, and then ask yourself, "How all this is done?" Go out in the evening and see the dew gather drop by drop upon the grass, or trace the delicate hoar-frost crystals which bespangle every blade on a winter's morning. Look at the vivid flashes of lightning in a storm, and listen to the pealing thunder: and then tell me, by what machinery is all this wonderful work done? Man does none of it, neither could he stop it if he were to try; for it is all the work of those invisible *forces* or *fairies* whose acquaintance I wish you to make. Day and night, summer and winter, storm or calm, these fairies are at work, and we may hear them and know them, and make friends of them if we will.

There is only one gift we must have before we can learn to know them—we must have *imagination.* I do not mean mere fancy, which creates unreal images and impossible monsters, but imagination, the power of making pictures or *images* in our mind, of that which *is,* though it is invisible to us. Most children have this glorious gift, and love to picture to themselves all that is told them, and to hear the same tale over and over again till they see every bit of it as if it were real. This is why they are sure to love science if its tales are told them aright; and I, for one, hope the day may never come when we may lose that childish clearness of vision, which enables us through the temporal things which are seen, to realize those eternal truths which are unseen.

If you have this gift of imagination come with me, and in these lectures we will look for the invisible fairies of nature.

Watch a shower of rain. Where do the drops come from? and why are they round, or rather slightly oval? In our fourth lecture we shall see that the little particles of water of which the rain-drops are made, were held apart and invisible in the air by *heat,* one of the most wonderful of our forces* or fairies, till the cold wind passed by and chilled the air. Then, when there was no longer so much heat, another invisible force, *cohesion,* which is always ready and waiting, seized on the tiny particles at once, and locked them together in a drop, the closest form in which they could lie. Then as the drops became larger and larger they fell into the grasp of another invisible force, *gravitation,* which dragged them down to the earth, drop by drop, till they made a shower of rain. Pause for a moment and think. You have surely heard of gravitation, by which the sun holds the earth and the planets, and keeps them moving round

* I am quite aware of the danger incurred by using this word "force," especially in the plural; and how even the most modest little book may suffer at the hands of scientific purists by employing it rashly. As, however, the better term "energy" would not serve here, I hope I may be forgiven for retaining the much-abused term, especially as I sin in very good company.

him in regular order? Well, it is this same gravitation which is at work also whenever a shower of rain falls to the earth. Who can say that he is not a great invisible giant, always silently and invisibly toiling in great things and small whether we wake or sleep? Now the shower is over, the sun comes out and the ground is soon as dry as though no rain had fallen. Tell me, what has become of the rain-drops? Part no doubt have sunk into the ground, and as for the rest, why you will say the sun has dried them up. Yes, but how? The sun is more than ninety-one millions of miles away; how has he touched the rain-drops? Have you ever heard that invisible waves are traveling every second over the space between the sun and us? We shall see in the next lecture how these waves are the sun's messengers to the earth, and how they tear asunder the rain-drops on the ground, scattering them in tiny particles too small for us to see, and bearing them away to the clouds. Here are more invisible fairies working every moment around you, and you cannot even look out of the window without seeing the work they are doing.

If, however, the day is cold and frosty, the water does not fall in a shower of rain; it comes down in the shape of noiseless snow. Go out after such a snow-shower, on a calm day, and look at some of the flakes which have fallen; you will see, if you choose good specimens, that they are not mere masses of frozen water, but that each one is a beautiful six-pointed crystal star. How have these crystals been built up? What power has been at work arranging their delicate forms? In the fourth lecture we shall see that up in the clouds another of our invisible fairies, which, for want of a better name, we call the "force of crystallization," has caught hold of the tiny particles of water before "cohesion" had made them into round drops, and there silently but rapidly, has moulded them into those delicate crystal stars know as "snow-flakes."

And now, suppose that this snow-shower has fallen early in February; turn aside for a moment from examining the flakes, and clear the newly-fallen snow from off the flower-bed on the lawn. What is this little green tip peeping up out of the ground under the snowy covering? It is a young snowdrop plant. Can you tell me why it grows? where it finds its food? what makes it spread out its leaves and add to its stalk day by day? What fairies are at work here?

First there is the hidden fairy "life," and of her even our wisest men know but little. But they know something of her way of working, and in Lecture VII. we shall learn how the invisible fairy sunbeams have been busy here also; how last year's snowdrop plant caught them and stored them up in its bulb, and how now in the spring, as soon as warmth and moisture creep down into the earth, these little imprisoned sun-waves begin to be active, stirring up the matter in the bulb, and making it swell and burst upwards till it sends out a little shoot through the surface of the soil. Then the sun-waves above-ground take up the work, and form green granules in the tiny leaves, helping them to take food out of the air, while the little rootlets below are drinking water out of the ground. The invisible life and invisible sunbeams are busy here, setting actively to work another fairy, the force of "chemical attraction," and so the little snowdrop plant grows and blossoms, without any help from you or me.

One picture more, and then I hope you will believe in my fairies. From the cold garden, you run into the house, and find the fire laid indeed in the grate, but the wood dead and the coals black, waiting to be lighted. You strike a match, and soon there is a blazing fire. Where does the heat come from? Why do the coals burn and give out a glowing light? Have you not read of gnomes buried down deep in the earth, in mines, and held fast there till some fairy wand has released them, and allowed them to come to earth again? Well, thousands and millions of years ago, those coals were plants; and, like the snowdrop in the garden of to-day, they caught the sunbeams and worked them into their leaves. Then the plants died and were buried deep in the earth and the sunbeams with them; and like the gnomes they lay imprisoned till the coals were dug out by the miners, and brought to your grate; and just now you yourself took hold of the fairy wand which was to release them. You struck a match, and its atoms clashing with atoms of oxygen in the air, set the invisible fairies "heat" and "chemical attraction" to work, and they were soon busy within the wood and the coals causing their atoms too to clash; and the sunbeams, so long imprisoned, leaped into flame. Then you spread out your hands and cried, "Oh, how nice and warm!" and little thought that you were warming yourself with the sunbeams of ages and ages ago.

This is no fancy tale; it is literally true, as we shall see in Lecture VIII., that the warmth of a coal fire could not exist if the plants of long ago had not used the sunbeams to make their leaves, holding them ready to give up their warmth again whenever those crushed leaves are consumed.

Now, do you believe in, and care for, my fairy-land? Can you see in your imagination fairy *Cohesion* ever ready to lock atoms together when they draw very near to each other: or fairy *Gravitation* dragging rain-drops down to the earth: or the fairy of *Crystallization* building up the snow-flakes in the clouds? Can you picture tiny sunbeam-waves of light and heat traveling from the sun to the earth? Do you care to know how another strange fairy, *'Electricity,'* flings the lightning across the sky and causes the rumbling thunder? Would you like to learn how the sun makes pictures of the world on which he shines, so that we can carry about with us photographs or sun-pictures of all the beautiful scenery of the earth? And have you any curiosity about *'Chemical action,'* which works such wonders in air, and land, and sea? If you have any wish to know and make friends of these invisible forces, the next question is

How are you to enter the fairy-land of science?

There is but one way. Like the knight or peasant in the fairy tales, you must open your eyes. There is no lack of objects: everything around you will tell some history if touched with the fairy wand of imagination. I have often thought, when seeing some sickly child drawn along the street, lying on its back while other children romp and play, how much happiness might be given to sick children at home or in hospitals, if only they were told the stories which lie hidden in the things around them. They need not even move from their beds, for sunbeams can fall on them there, and in a sunbeam there are stories enough to occupy a month. The fire in the grate, the lamp by the bedside, the water in the tumbler, the fly on the ceiling above, the flower in the vase on the table, anything, everything, has its history, and can reveal to us nature's invisible fairies.

Only you must wish to see them. If you go through the world looking upon everything only as so much to eat, to drink, and to use, you will never see the fairies of science. But if you ask yourself why things happen, and how the great God above us has made and governs this world of ours; if you listen to the wind, and care to learn why it blows; if you ask the little flower why it opens in the sunshine and closes in the storm; and if when you find questions you cannot answer, you will take the trouble to hunt out in books, or make experiments, to solve your own questions, then you will learn to know and love those fairies.

Mind, I do not advise you to be constantly asking questions of other people; for often a question quickly answered is quickly forgotten, but a difficulty really hunted down is a triumph for ever. For example, if you ask why the rain dries up from the ground, most likely you will be answered, "that the sun dries it," and you will rest satisfied with the sound of the words. But if you hold a wet handkerchief before the fire and see the damp rising out of it, then you have some real idea how moisture may be drawn up by heat from the earth.

A little foreign niece of mine, only four years old, who could scarcely speak English plainly, was standing one morning near the bed-room window and she noticed the damp trickling down the window-pane. "Auntie," she said, "what for it rain inside?" It was quite useless to explain to her in words, how our breath had condensed into drops of water upon the cold glass; but I wiped the pane clear, and breathed on it several times. When new drops were formed, I said, "Cissy and auntie have done like this all night in the room." She nodded her little head and amused herself for a long time breathing on the window-pane and watching the tiny drops; and about a month later, when we were traveling back to Italy, I saw her following the drops on the carriage window with her little finger, and heard her say quietly to herself, "Cissy and auntie made you." Had not even this little child some real picture in her mind of invisible water coming from her mouth, and making drops upon the window-pane?

Then again, you must learn something of the language of science. If you travel in a country with no knowledge of its language, you can learn very little about it; and in the same way if you are to go to books to find answers to your questions, you must know something of the language they speak. You need not learn hard scientific names, for the best books have the fewest of these, but you must really understand what is meant by ordinary words.

For example, how few people can really explain the difference between a *solid,* such as the wood of the table; a *liquid,* as water; and a *gas,* such as I can let off from this gas-jet by turning the tap. And yet any child can make a picture of this in his mind if only it has been properly put before him.

All matter in the world is made up of minute parts or particles; in a *solid* these particles are locked together so tightly that you must tear them forcibly apart if you wish to alter the shape of the solid piece. If I break or bend this wood I have to force the particles to move round each other, and I have great difficulty in doing it. But in a *liquid,* though the particles are still held together, they do not cling so tightly, but are able to roll or glide round each other, so that when you pour water out of a cup on to a table, it loses its cup-like shape and spreads itself out flat. Lastly, in a *gas* the particles are no longer held together at all, but they try to fly away from each other; and unless you shut a gas in tightly and safely, it will soon have spread all over the room.

A solid, therefore, will retain the same bulk and shape unless you forcibly alter it; a liquid will retain the same bulk, but not the same shape if it be left free; a gas will not retain either the same bulk or the same shape, but will spread over as large a space as it can find wherever it can penetrate. Such simple things as these you must learn from books and by experiment.

Then you must understand what is meant by *chemical attraction;* and though I can explain this roughly here, you will have to make many interesting experiments before you will really learn to know this wonderful fairy power. If I dissolve sugar in water, though it disappears it still remains sugar, and does not join itself to the water. I have only to let the cup stand till the water dries, and the sugar will remain at the bottom. There has been no chemical attraction here.

Piece of potassium in a basin of water

But now I will put something else in water which will call up the fairy power. Here is a little piece of the metal potassium, one of the simple substances of the earth; that is to say, we cannot split it up into other substances, wherever we find it, it is always the same. Now if I put this piece of potassium on the water it does not disappear quietly like the sugar. See how it rolls round and round, fizzing violently with a blue flame burning round it, and at last goes off with a pop.

What has been happening here?

You must first know that water is made of two substances, hydrogen and oxygen, and these are not merely held together, but are joined so completely that they have lost themselves and have become water; and each atom of water is made of two atoms of hydrogen and one of oxygen.

Now the metal potassium is devotedly fond of oxygen, and the moment I threw it on the water it called the fairy "chemical attraction" to help it, and dragged the atoms of oxygen out of the water and joined them to itself. In doing this it also caught part of the hydrogen, but only half, and so the rest was left out in the cold. No, not in the cold! for the potassium and oxygen made such a great heat in clashing together that the rest of the hydrogen became very hot indeed, and sprang into the air to find some other companion to make up for what it had lost. Here it found some free oxygen floating about, and it seized upon it so violently, that they made a burning flame, while the potassium with its newly-found oxygen and hydrogen sank down quietly into the water as *potash*. And so you see we have got quite a new substance *potash* in the basin; made with a great deal of fuss by *chemical attraction* drawing different atoms together.

When you can really picture this power to yourself it will help you very much to understand what you read and observe about nature.

Next, as plants grow around you on every side, and are of so much importance in the world, you must also learn something of the names of the different parts of a flower, so that you may understand those books which explain how a plant grows and lives and forms its seeds. You must also know the common names of the parts of an animal, and of your own body, so that you may be interested in understanding the use of the different organs; how you breathe, and how your blood flows; how one animal walks, another flies, and another swims. Then you must learn something of the various parts of the world, so that you may know what is meant by a river, a plain, a valley, or a delta. All these things are not difficult, you can learn them pleasantly from simple books on physics, chemistry, botany, physiology, and physical geography; and when you understand a few plain scientific terms, then all by yourself, if you will open your eyes and ears, you may wander happily in the fairy-land of science. Then wherever you go you will find

> "Tongues in trees, books in the running brooks,
> Sermons in stones, and good in everything."

And now we come to the last part of our subject. When you have reached and entered the gates of science, how are you to use and enjoy this new and beautiful land?

This is a very important question, for you may make a two-fold use of it. If you are only ambitious to shine in the world, you may use it chiefly to get prizes, to be at the top of your class, or to pass in examinations; but if you also enjoy discovering its secrets, and desire to learn more and more of nature and to revel in dreams of its beauty, then you will study science for its own sake as well. Now it is a good thing to win prizes and be at the top of your class, for it shows that you are industrious; it is a good thing to pass well in examinations, for it shows that you are accurate; but if you study science for this reason *only*, do not complain if you find it dull, and dry, and hard to master. You may learn a great deal that is useful, and nature will answer you truthfully if you ask your questions accurately, but she will give you dry facts, just such as you ask for. If you do not love her for herself she will never take you to her heart.

This is the reason why so many complain that science is dry and uninteresting. They forget that though it is necessary to learn accurately, for so only we can arrive at truth, it is equally necessary to love knowledge and make it lovely to those who learn, and to do this we must get at the spirit which lies under the facts. What child which loves its mother's face is content to know only that she has brown eyes, a straight nose, a small mouth, and hair arranged in such and such a manner? No, it knows that its mother has the sweetest smile of any woman living; that her eyes are loving, her kiss is sweet, and that when she looks grave, then something is wrong which must be put right. And it is in this way that those who wish to enjoy the fairy-land of science must love nature.

It is well to know that when a piece of potassium is thrown on water the change which takes place is expressed by the formula $K + H^2O = KHO + H$. But it is better still to have a mental picture of the tiny atoms clasping each other, and mingling so as to make a new substance, and to feel how wonderful are the many changing forms of nature. It is useful to be able to classify a flower and to know that the buttercup belongs to the Family Ranunculaceæ, with *petals free and definite, stamens hypogynous and indefinite, pistil apocarpous.* But it is far sweeter to learn about the life of the little plant, to understand why its peculiar flower is useful to it, and how it feeds itself, and makes its seed. No one can love dry facts; we must clothe them with real meaning and love the truths they tell, if we wish to enjoy science.

Let us take an example to show this. I have here a branch of white coral, a beautiful, delicate piece of nature's work. We will begin by copying a description of it from one of those class-books which suppose children to learn words like parrots, and to repeat them with just as little understanding.

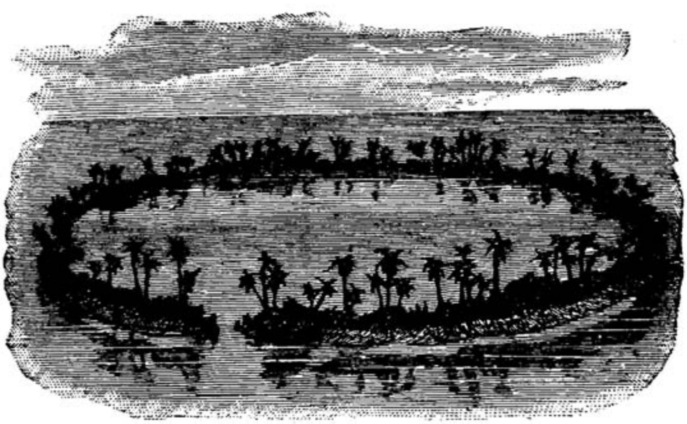
"Coral is formed by an animal belonging to the kingdom of *Radiates,* sub-kingdom *Polypes.* The soft body of the animal is attached to a support, the mouth opening upwards in a row of tentacles. The coral is secreted in the body of the polyp out of the carbonate of lime in the sea. Thus the coral animalcule rears its polypidom or rocky structure in warm latitudes, and constructs reefs or barriers round islands. It is limited in rage of depth from 25 to 30 fathoms. Chemically considered, coral is carbonate of lime; physiologically, it is the skeleton of an animal; geographically, it is characteristic of warm latitudes, especially of the Pacific Ocean." This description is correct, and even fairly complete, if you know enough of the subject to understand it. But tell me, does it lead you to love my piece of coral? Have you any picture in your mind of the coral animal, its home, or its manner of working?

But now, instead of trying to master this dry, hard passage, take Mr. Huxley's penny lecture on "Coral and Coral Reefs,"[*] and with the piece of coral in your hand, try really to learn its history. You will then be able to picture to yourself the coral animal as a kind of sea-anemone, something like those which you have often seen, like red, blue, or green flowers, putting out their feelers in sea-water on our coasts, and drawing in the tiny sea-animals to digest them in that bag of fluid which serves the sea-anemone as a stomach. You will learn how this curious jelly animal can split itself in two, and so form two polyps, or send a bud out of its side and so grow up into a kind of "tree or bush of polyps," or how it can hatch little eggs inside it and throw out young ones from its

[*] "Manchester Science Lectures," No. 1, Second Series. John Heywood, 141, Deansgate, Manchester.

mouth, provided with little hairs, by means of which they swim to new resting places. You will learn the difference between the animal which builds up the red coral as its skeleton, and the group of animals which build up the white; and you will look with new interest on our piece of white coral, as you read that each of those little cups on its stem with delicate divisions like the spokes of a wheel has been the home of a separate polyp, and that from the sea-water each little jelly animal has drunk in carbonate of lime as you drink in sugar dissolved in water, and then has used it grain by grain to build that delicate cup and add to the coral tree.

We cannot stop to examine all about coral now; we are only learning how to learn, but surely our specimen is already beginning to grow interesting, and when you have followed it out into the great Pacific Ocean, where the wild waves dash



Coral island in the Pacific.

restlessly against the coral trees, and have seen these tiny drops of jelly conquering the sea and building huge walls of stone against the rough breakers, you will hardly rest till you know all their history. Look at that curious circular island in the picture, covered with palm trees; it has a large smooth lake in the middle, and the bottom of this lake is covered with blue, red, and green jelly animals, spreading out their feelers in the water and looking like beautiful flowers, and all round the outside of the island similar animals are to be seen washed by the sea waves. Such islands as this have been built entirely by the coral animals, and the history of the way in which the reefs have sunk gradually down, as the tiny creatures added to them inch by inch, is as fascinating as the story of the building of any fairy palace in the days of old. Read all this, and then if you have no coral of your own to examine, go to the British Museum* and see the beautiful specimens in the glass cases there, and think that they have been built up under the rolling surf by the tiny jelly animals; and then coral will become a real living thing to you, and you will love the thoughts it awakens.

But people often ask, what is the use of learning all this? If you do not feel by this time how delightful it is to fill your mind with beautiful pictures of nature, perhaps it would be useless to say more. But in this age of ours, when restlessness and love of excitement pervade so many lives, is it nothing to be taken out of ourselves and made to

* These specimens are eventually going to South Kensington.

look at the wonders of nature going on around us? Do you never feel tired and "out of sorts," and want to creep away from your companions, because they are merry and you are not? Then is the time to read about the stars, and how quietly they keep their course from age to age; or to visit some little flower, and ask what story it has to tell; or to watch the clouds, and try to imagine how the winds drive them across the sky. No person is so independent as he who can find interest in a bare rock, a drop of water, the foam of the sea, the spider on the wall, the flower underfoot or the stars overhead. And these interests are open to everyone who enters the fairy-land of science.

Moreover, we learn from this study to see that there is a law and purpose in everything in the Universe, and it makes us patient when we recognize the quiet noiseless working of nature all around us. Study light, and learn how all color, beauty, and life depend on the sun's rays; note the winds and currents of the air, regular even in their apparent irregularity, as they carry heat and moisture all over the world. Watch the water flowing in deep quiet streams, or forming the vast ocean; and then reflect that every drop is guided by invisible forces working according to fixed laws. See plants springing up under the sunlight, learn the secrets of plant life, and how their scents and colors attract the insects. Read how insects cannot live without plants, nor plants without the flitting butterfly or the busy bee. Realize that all this is worked by fixed laws, and that out of it (even if sometimes in suffering and pain) springs the wonderful universe around us. And then say, can you fear for your own little life, even though it may have its troubles? Can you help feeling a part of this guided and governed nature? or doubt that the power which fixed the laws of the stars and of the tiniest drop of water—that made the plant draw power from the sun, the tiny coral animal its food from the dashing waves; that adapted the flower to the insect, and the insect to the flower—is also moulding your life as part of the great machinery of the universe, so that you have only to work, and to wait, and to love?

We are all groping dimly for the Unseen Power, but no one who loves nature and studies it can ever feel alone or unloved in the world. Facts, as mere facts, are dry and barren, but nature is full of life and love, and her calm unswerving rule is tending to some great though hidden purpose. You may call this Unseen Power what you will—may lean on it in loving, trusting faith, or bend in reverent and silent awe; but even the little child who lives with nature and gazes on her with open eye, must rise in some sense or other through nature to nature's God.

LECTURE II

SUNBEAMS AND THE WORK THEY DO

WHO does not love the sunbeams, and feel brighter and merrier as he watches them playing on the wall, sparkling like diamonds on the ripples of the sea, or making bows of colored light on the waterfall? Is not the sunbeam so dear to us that it has become a household word for all that is merry and gay? and when we want to describe the dearest, busiest little sprite amongst us, who wakes a smile on all faces wherever she goes, do we not call her the "sunbeam of the house?"

And yet how little even the wisest among us know about the nature and work of these bright messengers of the sun as they dart across space!

Did you ever wake quite early in the morning, when it was pitch-dark and you could see nothing, not even your own hand; and then lie watching as time went on till the light came gradually creeping in at the window? If you have done this you will have noticed that you can at first only just distinguish the dim outline of the furniture; then you can tell the difference between the white cloth on the table and the dark wardrobe beside it; then by degrees all the smaller details, the handles of the drawer, the pattern on the wall, and the different colors of all the objects in the room become clearer and clearer till at last you see all distinctly in broad daylight.

What has been happening here? and why have the things in the room become visible by such slow degrees? We say that the sun is rising, but we know very well that it is not the sun which moves, but that our earth has been turning slowly round, and bringing the little spot on which we live face to face with the great fiery ball, so that his beams can fall upon us.

Take a small globe, and stick a piece of black plaster over England, then let a lighted lamp represent the sun, and turn the globe slowly, so that the spot creeps round from the dark side away from the lamp, until it catches, first the rays which pass along the side of the globe, then the more direct rays, and at last stands fully in the blaze of the light. Just this was happening to our spot of the world as you lay in bed and saw the light appear; and we have to learn to-day what those beams are which fall upon us and what they do for us.

First we must learn something about the sun itself, since it is the starting-place of all the sunbeams. If the sun were a dark mass instead of a fiery one we should have none of these bright cheering messengers, and though we were turned face to face with him every day we should remain in one cold eternal night. Now you will remember we mentioned in the last lecture that it is heat which shakes apart the little atoms of water and makes them float up in the air to fall again as rain; and that if the day is cold they fall as snow, and all the water is turned into ice. But if the sun were altogether dark, think how bitterly cold it would be; far colder than the most wintry weather ever known, because in the bitterest night some warmth comes out of the earth, where it has been stored from the sunlight which fell during the day. But if we never received any warmth at all, no water would ever rise up into the sky, no rain ever fall, no rivers flow, and consequently no plants could grow and no animals live. All water would be in the form of snow and ice, and the earth would be one great frozen mass with nothing moving upon it.

So you see it becomes very interesting for us to learn what the sun is, and how he sends us his beams. How far away from us do you think he is? On a fine summer's day when we can see him clearly, it looks as if we had only to get into a balloon and reach him as he sits in the sky, and yet we know roughly that he is more than ninety-one millions of miles distant from our earth.

These figures are so enormous that you cannot really grasp them. But imagine yourself in an express train, travelling at the tremendous rate of sixty miles an hour and never stopping. At that rate, if you wished to arrive at the sun to-day you would have been obliged to start 171 years ago. That is, you must have set off in the early part of the reign of

Queen Anne, and you must have gone on, never, never resting, through the reigns of George I., George II., and the long reign of George III., then through those of George IV., William IV., and Victoria, whirling on day and night at express speed, and at last, to-day, you would have reached the sun!

And when you arrived there, how large do you think you would find him to be? Anaxagoras, a learned Greek, was laughed at by all his fellow Greeks because he said that the sun was as large as the Peloponnesus, that is about the size of Middlesex. How astonished they would have been if they could have known that not only is he bigger than the whole of Greece, but more than a million times bigger than the whole world!

Our world itself is a very large place, so large that our own country looks only like a tiny speck upon it, and an express train would take nearly a month to travel round it. Yet even our whole globe is nothing in size compared to the sun, for it only measures 8000 miles across, while the sun measures more than 852,000.

Imagine for a moment that you could cut the sun and the earth each in half as you would cut an apple; then if you were to lay the flat side of the half-earth on the flat side of the half sun it would take 106 such earths to stretch across the face of the sun. One of these 106 round spots on the diagram represents the size which our earth would look if placed on the sun; and they are so tiny compared to him that they look only like a string of minute beads stretched across his face. Only think, then, how many of these minute dots would be required to fill the whole of the inside if it were a globe!

One of the best ways to form an idea of the whole size of the sun is to imagine it to be hollow, like an air-ball, and then see how many earths it would take to fill it. You would hardly believe that it would take one million, three hundred and thirty-one thousand globes the size of our world squeezed together. Just think, if a huge giant could travel all over the universe and gather worlds, all as big as ours, and were to make first a heap of merely ten such worlds, how huge it would be! Then he must have a hundred such heaps of ten to make a thousand worlds; and then he must collect again *a thousand times that thousand to make a million,* and when he had stuffed them all into the sun-ball he would still have only filled three-quarters of it!

After hearing this you will not be astonished that such a monster should give out an enormous quantity of light and heat; so enormous that it is almost impossible to form any idea of it. Sir John Herschel has, indeed, tried to picture it for us. He found that a ball of lime with a flame of oxygen and hydrogen playing round it (such as we use in magic lanterns and call oxy-hydrogen light) becomes so violently hot that it gives the most brilliant artificial light we can get—such that you cannot put your eye near it without injury. Yet if you wanted to have a light as strong as that of our sun, it would not be enough to make such a lime-ball as big as the sun is. No, you must make it as big as 146 suns, or more than 146,000,000 times as big as our earth, in order to get the right amount of light. Then you would have a tolerably good artificial sun; for we know that the body of the sun gives out an intense white light, just as the lime-ball does, and that, like it, it has an atmosphere of glowing gases round it.

But perhaps we get the best idea of the mighty heat and light of the sun by remembering how few of the rays which dart out on all sides from this fiery ball can reach our tiny globe, and yet how powerful they are. Look at the globe of a lamp in the middle of the room, and see how its light pours out on all sides and into every corner; then take a grain of mustard-seed, which will very well represent the comparative size of our earth, and hold it up at a distance from the lamp. How very few of all those rays which are filling the room fall on the little mustard-seed, and just so few does our earth catch of the rays which dart out from the sun. And yet this small quantity (1/2000-millionth part of the whole) does nearly all the work of our world.[*]

In order to see how powerful the sun's rays are, you have only to take a magnifying glass and gather them to a point on a piece of brown paper, for they will set the paper alight. Sir John Herschel tells us that at the Cape of Good Hope the heat was even so great that he cooked a beefsteak and roasted some eggs by merely putting them in the sun, in a

[*] These and the preceding numerical statements will be found worked out in Sir J. Herschel's "Familiar Lectures on Scientific Subjects," 1868, from which many of the facts in the first part of the lecture are taken.

box with a glass lid! Indeed, just as we should all be frozen to death if the sun were cold, so we should all be burnt up with intolerable heat if his fierce rays fell with all their might upon us. But we have an invisible veil protecting us, made—of what do you think? Of those tiny particles of water which the sunbeams draw up and scatter in the air, and which, as we shall see in Lecture IV., cut off part of the intense heat and make the air cool and pleasant for us.

We have now learned something of the distance, the size, the light, and the heat of the sun—the great source of the sunbeams. But we are as yet no nearer the answer to the question, What is a sunbeam? how does the sun touch our earth?

Now suppose I wish to touch you from this platform where I stand, I can do it in two ways. Firstly, I can throw something at you and hit you—in this case a *thing* will have passed across the space from me to you. Or, secondly, if I could make a violent movement so as to shake the floor of the room, you would feel a quivering motion; and so I should touch you across the whole distance of the room. But in this case no *thing* would have passed from me to you but a movement or *wave,* which passed along the boards of the floor. Again, if I speak to you, how does the sound reach your ear? Not by anything being thrown from my mouth to your ear, but by the motion of the air. When I speak I agitate the air near my mouth, and that makes a wave in the air beyond, and that one, another, and another (as we shall see more fully in Lecture VI.) till the last wave hits the drum of your ear.

Thus we see there are two ways of touching anything at a distance; 1st, by throwing some *thing* at it and hitting it; 2d, by sending a movement or *wave* across to it, as in the case of the quivering boards and the air.

Now the great natural philosopher Newton thought that the sun touched us in the first of these ways, and that sunbeams were made of very minute atoms of matter thrown out by the sun, and making a perpetual cannonade on our eyes. It is easy to understand that this would make us see light and feel heat, just as a blow in the eye makes us see stars, or on the body makes it feel hot: and for a long time this explanation was supposed to be the true one. But we know now that there are many facts which cannot be explained on this theory, though we cannot go into them here. What we will do, is to try and understand what now seems to be the true explanation of the sunbeam.

About the same time that Newton wrote, a Dutchman, named Huyghens, suggested that light comes from the sun in tiny waves, travelling across space much in the same way as ripples travel across a pond. The only difficulty was to explain in what substance these waves could be travelling: not through water, for we know that there is no water in space—nor through air, for the air stops at a comparatively short distance from our earth. There must then be something filling all space between us and the sun, finer than either water or air.

And now I must ask you to use all your imagination, for I want you to picture to yourselves something quite as invisible as the Emperor's new clothes in Andersen's fairy-tale, only with this difference, that our invisible *something* is very active; and though we can neither see it nor touch it we know it by its effects. You must imagine a fine substance filling all space between us and the sun and the stars. A substance so very delicate and subtle, that not only is it invisible, but it can pass through solid bodies such as glass, ice, or even wood or brick walls. This substance we call "ether." I cannot give you here the reasons why we must assume that it is throughout all space; you must take this on the word of such men as Sir John Herschel or Professor Clerk-Maxwell, until you can study the question for yourselves.

Now if you can imagine this ether filling every corner of space, so that it is everywhere and passes through everything, ask yourselves, what must happen when a great commotion is going on in one of the large bodies which float in it? When the atoms of the gases round the sun are clashing violently together to make all its light and heat, do you not think they must shake this ether all around them? And then, since the ether stretches on all sides from the sun to our earth and all other planets, must not this quivering travel to us, just as the quivering of the boards would from me to you? Take a basin of water to represent the ether, and take a piece of potassium like that which we used in our last lecture, and hold it with a pair of nippers in the middle of the water. You will see that as the potassium hisses and the flame burns round it, they will make waves which will travel all over the water to the edge of the basin, and you can imagine how in the same way waves travel over the ether from the sun to us.

Straight away from the sun on all sides, never stopping, never resting, but chasing after each other with marvellous quickness, these tiny waves travel out into space by night and by day. When our spot of the earth where England lies is turned away from them and they cannot touch us, then it is night for us, but directly England is turned so as to face the sun, then they strike on the land, and the water, and warm it; or upon our eyes, making the nerves quiver so that we see light. Look up at the sun and picture to yourself that instead of one great blow from a fist causing you to see stars for a moment, millions of tiny blows from these sun-waves are striking every instant on your eye; then you will easily understand that this would cause you to see a constant blaze of light.

But when the sun is away, if the night is clear we have light from the stars. Do these then too make waves all across the enormous distance between them and us? Certainly they do, for they too are suns like our own, only they are so far off that the waves they send are more feeble, and so we only notice them when the sun's stronger waves are away.

But perhaps you will ask, if no one has ever seen these waves nor the ether in which they are made, what right have we to say they are there? Strange as it may seem, though we cannot see them we have measured them and know how large they are, and how many can go into an inch of space. For as these tiny waves are running on straight forward through the room, if we put something in their way, they will have to run round it; and if you let in a very narrow ray of light through a shutter and put an upright wire in the sunbeam, you actually make the waves run round the wire just as water runs round a post in a river; and they meet behind the wire, just as the water meets in a V shape behind the post. Now when they meet, they run up against each other, and here it is we catch them. For if they meet comfortably, both rising up in a good wave, they run on together and make a bright line of light; but if they meet higgledy-piggledy, one up and the other down, all in confusion, they stop each other, and then there is no light but a line of darkness. And so behind your piece of wire you can catch the waves on a piece of paper, and you will find they make dark and light lines one side by side with the other, and by means of these bands it is possible to find out how large the waves must be. This question is too difficult for us to work it out here, but you can see that large waves will make broader light and dark bands than small ones will, and that in this way the size of the waves may be measured.

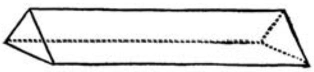
And now, how large do you think they turn out to be? So very, very tiny that about fifty thousand waves are contained in a single inch of space! I have drawn on the board the length of an inch, and now I will measure the same space in the air between my finger and thumb. Within this space at this moment there are fifty thousand tiny waves moving up and down. I promised you we would find in science things as wonderful as in fairy tales. Are not these tiny invisible messengers coming incessantly from the sun as wonderful as any fairies? and still more so when, as we shall see presently, they are doing nearly all the work of our world.

We must next try to realize how fast these waves travel. You will remember that an express train would take 171 years to reach us from the sun; and even a cannon-ball would take from ten to thirteen years to come that distance. Well, these tiny waves take only *seven minutes and a half* to come the whole 91 millions of miles. The waves which are hitting your eye at this moment are caused by a movement which began at the sun only 7 1/2 minutes ago. And remember, this movement is going on incessantly, and these waves are always following one after the other so rapidly that they keep up a perpetual cannonade upon the pupil of your eye. So fast do they come that about 608 billion waves enter your eye in one single second.* I do not ask you to remember these figures; I only ask you to try and picture to yourselves these infinitely tiny and active

* Light travels at the rate of 190,000 miles, or 12,165,120,000 inches in a second. Taking the average number of wave-lengths in an inch at 50,000, then 12,165,120,000 X 50,000 = 608,256,000,000,000.

invisible messengers from the sun, and to acknowledge that light is a fairy thing.

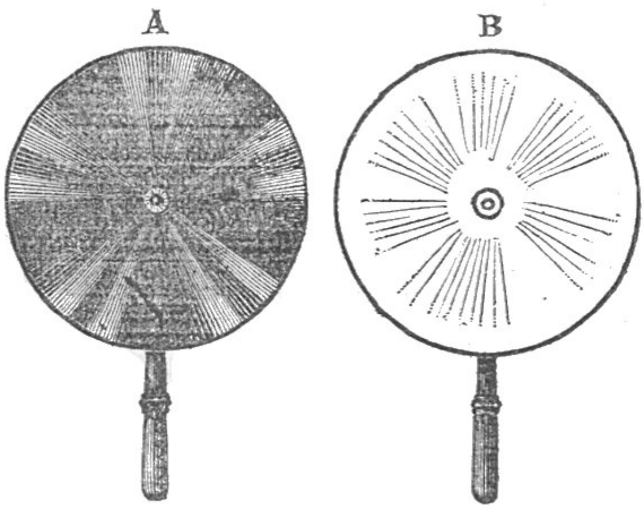
But we do not yet know all about our sunbeams. See, I have here a piece of glass with three sides, called a prism. If I put it in the sunlight



which is streaming through the window, what happens? Look! on the table there is a line of beautiful colors. I can make it long or short, as I turn the prism, but the colors always remain arranged in the same way. Here at my left hand is the red, beyond it orange, then yellow, green, blue, indigo or deep blue, and violet, shading one into the other all along the line. We have all seen these colors dancing on the wall when the sun has been shining brightly on the cut-glass pendants of the chandelier, and you may see them still more distinctly if you let a ray of light into a darkened room, and pass it through the prism. What are these colors? Do they come from the glass? No; for you will remember to have seen them in the rainbow, and in the soap-bubble, and even in a drop of dew or the scum on the top of a pond. This beautiful colored line is only our sunbeam again, which has been split up into many colors by passing through the glass, as it is in the rain-drops of the rainbow and the bubbles of the scum of the pond.

Till now we have talked of the sunbeam as if it were made of only one set of waves, but in truth it is made of many sets of waves of different sizes, all travelling along together from the sun. These various waves have been measured, and we know that the waves which make up red light are larger and more lazy than those which make violet light, so that there are only thirty-nine thousand red waves in an inch, while there are fifty-seven thousand violet waves in the same space.

How is it then, that if all these different waves making different colors, hit on our eye, they do not always make us see colored light? Because, unless they are interfered with, they all travel along together, and you know that all colors, mixed together in proper proportion, make white.



A. Cardboard painted with the seven colors in succession.

B. Same cardboard spun quickly round.

I have here a round piece of cardboard, painted with the seven colors in succession several times over. When it is still you can distinguish them all apart, but when I whirl it quickly around—see!—the cardboard looks quite white, because we see them all so instantaneously that they are mingled together. In the same way light looks white to you, because all the different colored waves strike on your eye at once. You can easily make one of these cards for yourselves only the white will always look dirty, because you cannot get the colors pure.

Now, when the light passes through the three-sided glass or prism, the waves are spread out, and the slow, heavy, red waves lag behind and remain at the lower end of the colored line on the wall, while the rapid little violet waves are bent more out of their road and run to the farther end of the line; and the orange, yellow, green, blue, and indigo arrange themselves between, according to the size of their waves.

And now you are very likely eager to ask why the quick waves should make us see one color, and the slow waves another. This is a very difficult question, for we have a great deal still to learn about the effect of light on the eye. But you can easily imagine that color is to our eye much the same as music is to our ear. You know we can distinguish different notes when the air-waves play slowly or quickly upon the drum of the ear (as we shall see in Lecture VI.) and somewhat in the same way the tiny waves of the ether play on the retina or curtain at the back of our eye, and make the nerves carry different messages to the brain: and the color we see depends upon the number of waves which play upon the retina in a second.

Do you think we have now rightly answered the question—What is a sunbeam? We have seen that it is really a succession of tiny rapid waves, traveling from the sun to us across the invisible substance we call "ether," and keeping up a constant cannonade upon everything which comes in their way. We have also seen that, tiny as these waves are, they can still vary in size, so that one single sunbeam is made up of myriads of different-sized waves, which travel all together and make us see white light; unless for some reason they are scattered apart, so that we see them separately as red, green, blue, or yellow. How they are scattered, and many other secrets of the sun-waves, we cannot stop to consider now, but must pass on to ask—

What work do the sunbeams do for us?

They do two things—they give us light and heat. It is by means of them alone that we see anything. When the room was dark you could not distinguish the table, the chairs, or even the walls of the room. Why? Because they had no light-waves to send to your eye. But as the sunbeams began to pour in at the window, the waves played upon the things in the room, and when they hit them they bounded off them back to your eye, as a wave of the sea bounds back from a rock and strikes against a passing boat. Then, when they fell upon your eye, they entered it and excited the retina and the nerves, and the image of the chair or the table was carried to your brain. Look around at all the things in this room. Is it not strange to think that each one of them is sending these invisible messengers straight to your eye as you look at it; and that you see me, and distinguish me from the table, entirely by the kind of waves we each send to you?

Some substances send back hardly any waves of light, but let them all pass through them, and thus we cannot see them. A pane of clear glass, for instance, lets nearly all the light-waves pass through it, and therefore you often cannot see that the glass is there, because no light-messengers come back to you from it. Thus people have sometimes walked up against a glass door and broken it, not seeing it was there. Those substances are transparent which, for some reason unknown to us, allow the ether waves to pass through them without shaking the atoms of which the substance is made. In clear glass, for example, all the light-waves pass through without affecting the substance of the glass; while in a white wall the larger part of the rays are reflected back to your eye, and those which pass into the wall, by giving motion to its atoms lose their own vibrations.

Into polished shining metal the waves hardly enter at all, but are thrown back from the surface; and so a steel knife or a silver spoon are very bright, and are clearly seen. Quicksilver is put at the back of looking-glasses because it reflects so many waves. It not only sends back those which come from the sun, but those, too, which come from your face. So, when you see yourself in a looking-glass, the sun-waves have first played on your face and bounded off from it to the looking-glass; then, when they strike the looking-glass, they are thrown back again on to the retina of your eye, and you see your own face by means of the very waves you threw off from it an instant before.

But the reflected light-waves do more for us than this. They not only make us see things, but they make us see them in different colors. What, you will ask, is this too the work of the sunbeams? Certainly; for if the color we see depends on the size of the waves which come back to us, then we must see things colored differently according to the waves they send back. For instance, imagine a sunbeam playing on a leaf: part of its waves bound straight back from it to our eye and make us see the surface of the leaf, but the rest go right into the leaf itself, and there some of them are used up and kept prisoners. The red, orange, yellow, blue, and violet waves are all useful to the leaf, and it does not let them go again. But it cannot absorb the green waves, and so it throws them back, and they travel to your eye and make you see a green color. So when you say a leaf is green, you mean that the leaf does not want the green waves of the sunbeam, but sends them back to you. In the same way the scarlet geranium rejects the red waves; this table sends back brown waves; a white tablecloth sends back nearly the whole of the waves, and a black coat scarcely any. This is why, when there is very little light in the room, you can see a white tablecloth while you would not be able to distinguish a black object, because the few faint rays that are there, are all sent back to you from a white surface.

Is it not curious to think that there is really no such thing as color *in* the leaf, the table, the coat, or the geranium flower, but we see them of different colors because, for some reason, they send back only certain colored waves to our eye?

Wherever you look, then, and whatever you see, all the beautiful tints, colors, lights, and shades around you are the work of the tiny sun-waves.

Again, light does a great deal of work when it falls upon plants. Those rays of light which are caught by the leaf are by no means idle; we shall see in Lecture VII. that the leaf uses them to digest its food and make the sap on which the plant feeds.

We all know that a plant becomes pale and sickly if it has not sunlight, and the reason is, that without these light-waves it cannot get food out of the air, nor make the sap and juices which it needs. When you look at plants and trees growing in the beautiful meadows; at the fields of corn, and at the lovely landscape, you are looking on the work of the tiny waves of light, which never rest all through the day in helping to give life to every green thing that grows.

So far we have spoken only of light; but hold your hand in the sun and feel the heat of the sunbeams, and then consider if the waves of heat do not do work also. There are many waves in a sunbeam which move too slowly to make us see light when they hit our eye, but we can feel them as heat, though we cannot see them as light. The simplest way of feeling heat-waves is to hold a warm iron near your face. You know that no light comes from it, yet you can feel the heat-waves beating violently against your face and scorching it. Now there are many of these dark heat-rays in a sunbeam, and it is they which do most of the work in the world.

In the first place, as they come quivering to the earth, it is they which shake the water-drops apart, so that these are carried up in the air, as we shall see in the next lecture. And then remember, it is these drops, falling again as rain, which make the rivers and all the moving water on the earth. So also it is the heat-waves which make the air hot and light, and so cause it to rise and make winds and air-currents, and these again give rise to ocean-currents. It is these dark rays, again, which strike upon the land and give it the warmth which enables plants to grow. It is they also which keep up the warmth in our own bodies, both by coming to us directly from the sun, and also in a very roundabout way through plants. You will remember that plants use up rays of light and heat in growing; then either we eat the plants, or animals eat the plants and we eat the animals; and when we digest the food, that heat comes back in our bodies, which the plants first took from the sunbeams. Breathe upon your hand, and feel how hot your breath is; well, that heat which you feel, was once in a sunbeam, and has traveled from it through the food you have eaten, and has now been at work keeping up the heat of your body.

But there is still another way in which these plants may give out the heat-waves they have imprisoned. You will remember how we learned in the first lecture that coal is made of plants, and that the heat they give out is the heat these plants once took in. Think how much work is done by burning coals. Not only are our houses warmed by coal fires and lighted by coal gas, but our steam-engines and machinery work entirely by water which has been turned into steam by the heat of coal and coke fires; and our steamboats travel all over the world by means of the same power. In the same way the oil of our lamps comes either from olives, which grow on trees; or from coal and the remains of plants and animals in the earth. Even our tallow candles are made of mutton fat, and sheep eat grass; and so, turn which way we will, we find that the light and heat on our earth, whether it comes from fires, or candles, or lamps, or gas, and whether it moves machinery, or drives a train, or propels a ship, is equally the work of the invisible waves of ether coming from the sun, which make what we call a sunbeam.

Lastly, there are still some hidden waves which we have not yet mentioned, which are not useful to us either as light or heat, and yet they are not idle.

Before I began this lecture, I put a piece of paper, which had been dipped in nitrate of silver, under a piece of glass; and between it and the glass I put a piece of lace. Look what the sun has been doing while I have been speaking. It has been breaking up the nitrate of silver on the paper and turning it into a deep brown substance; only where the threads of the lace were, and the sun could not touch the nitrate of silver, there the paper has remained light-colored, and by this means I have a beautiful impression of the lace on the paper. I will now dip the impression into water in which some hyposulphite of soda is dissolved, and this will "fix" the picture, that is, prevent the sun acting upon it any more; then the picture will remain distinct, and I can pass it round to you all. Here, again, invisible waves have been at work, and this time neither as light nor as heat, but as chemical agents, and it is these waves which give us all our beautiful photographs. In any toy shop you can buy this prepared paper, and set the chemical waves at work to make pictures. Only you must remember to fix it in the solution afterwards, otherwise the chemical rays will go on working after you have taken the lace away, and all the paper will become brown and your picture will disappear.

And now, tell me, may we not honestly say, that the invisible waves which make our sunbeams, are wonderful fairy messengers as they travel eternally and unceasingly across space, never resting, never tiring in doing the work of our world? Little as we have been able to learn about them in one short hour, do they not seem to you worth studying and worth thinking about, as we look at the beautiful results of their work? The ancient Greeks worshipped the sun, and condemned to death one of their greatest philosophers, named Anaxagoras, because he denied that it was a god. We can scarcely wonder at this when we see what the sun does for our world; but *we* know that it is a huge globe made of gases and fiery matter, and not a god. We are grateful *for* the sun instead of *to* him, and surely we shall look at him with new interest, now that we can picture his tiny messengers, the sunbeams, flitting over all space, falling upon our earth, giving us light to see with, and beautiful colors to enjoy, warming the air and the earth, making the refreshing rain, and, in a word, filling the world with life and gladness.