Excerpts from

The Fairy-Land of Science

by Arabella Buckley

for Mater Amabilis Level 1A, Year 2

1.

from THE AERIAL OCEAN IN WHICH WE LIVE

“The Air Around Us”

Did you ever sit on the bank of a river in some quiet spot where the water was deep and clear, and watch the fishes swimming lazily along? When I was a child this was one of my favourite occupations in the summer-time on the banks of the Thames, and there was one question which often puzzled me greatly, as I watched the minnows and gudgeon gliding along through the water. Why should fishes live in something and be often buffeted about by waves and currents, while I and others lived on the top of the earth and not in anything? I do not remember ever asking anyone about this; and if I had, in those days people did not pay much attention to children's questions, and probably nobody would have told me, what I now tell you, that we do live in something quite as real and often quite as rough and stormy as the water in which the fishes swim. The something in which we live is air, and the reason that we do not perceive it, is that we are in it, and that it is a gas and invisible to us; while we are above the water in which the fishes live, and it is a liquid which our eyes can perceive.

But let us suppose for a moment that a being, whose eyes were so made that he could see gases as we see liquids, was looking down from a distance upon our earth. He would see an ocean of air, or aerial ocean, all round the globe, with birds floating about in it, and people walking along the bottom, just as we see fish gliding along the bottom of a river. It is true, he would never see even the birds come near to the surface, for the highest-flying bird, the condor, never soars more than five miles from the ground, and our atmosphere, as we shall see, is at least 100 miles high. So he would call us all deep-air creatures, just as we talk of deep-sea animals; and if we can imagine that he fished in this air-ocean, and could pull one of us out of it into space, he would find that we should gasp and die just as fishes do when pulled out of the water.

He would also observe very curious things going on in our air-ocean; he would see large streams and currents of air, which we call winds, and which would appear to him as ocean-currents do to us, while near down to the earth he would see thick mists forming and then disappearing again, and these would be our clouds. From them he would see rain, hail and snow falling to the earth, and from time to time bright flashes would shoot across the air-ocean, which would be our lightning. Nay even the brilliant rainbow, the northern aurora borealis, and the falling stars, which seem to us so high up in space, would be seen by him near to our earth, and all within the aerial ocean.

But as we know of no such being living in space, who can tell us what takes place in our invisible air, and we cannot see it ourselves, we must try by experiments to see it with our imagination, though we cannot with our eyes.

First, then, can we discover what air is? At one time it was thought that it was a simple gas and could not be separated into more than one kind. But we are now going to make an experiment by which it has been shown that air is made of two gases mingled together, and that one of these gases, called oxygen, is used up when anything burns, while the other nitrogen is not used, and only serves to dilute the minute atoms of oxygen. I can take a jar and place the jar over a flat dish of water with a candle secured in the middle. You can see that by putting the jar over the water, I have shut in a certain quantity of air, and my object now is to use up the oxygen out of this air and leave only nitrogen behind. To do this I must light the candle, for you will remember it is in burning that oxygen is used up and the candle, no longer able to burn without water, is extinguished.

2.

from THE AERIAL OCEAN IN WHICH WE LIVE

“What Is Air?”

Consider for a moment what we have done. First, the jar was full of air, that is, of mixed oxygen and nitrogen; then the burning candle used up the oxygen. Now nitrogen is the only gas left, and the water has risen up to fill all the rest of the space that was once taken up with the oxygen.

When this experiment is made very accurately, we find that for every pint of oxygen in air there are four pints of nitrogen, so that the active oxygen-atoms are scattered about, floating in the sleepy, inactive nitrogen.

It is these oxygen-atoms which we use up when we breathe. If I had put a mouse under the bell-jar, instead of the phosphorus, the water would have risen just the same, because the mouse would have breathed in the oxygen and used it up in its body, joining it to carbon and making a bad gas, carbonic acid, which would also melt in the water, and when all the oxygen was used, the mouse would have died.

Perhaps you will say, If oxygen is so useful, why is not the air made entirely of it? But think for a moment. If there was such an immense quantity of oxygen, how fearfully fast everything would burn! Our bodies would soon rise above fever heat from the quantity of oxygen we should take in, and all fires and[Pg 55] lights would burn furiously. In fact, a flame once lighted would spread so rapidly that no power on earth could stop it, and everything would be destroyed. So the lazy nitrogen is very useful in keeping the oxygen-atoms apart; and we have time, even when a fire is very large and powerful, to put it out before it has drawn in more and more oxygen from the surrounding air. Often, if you can shut a fire into a closed space, as in a closely-shut room or the hold of a ship, it will go out, because it has used up all the oxygen in the air.

So, you see, we shall be right in picturing this invisible air all around us as a mixture of two gases. But when we examine ordinary air very carefully, we find small quantities of other gases in it, besides oxygen and nitrogen: carbon dioxide, argon, hydrogen, water vapor, and traces of other gases.

3.

from THE AERIAL OCEAN IN WHICH WE LIVE

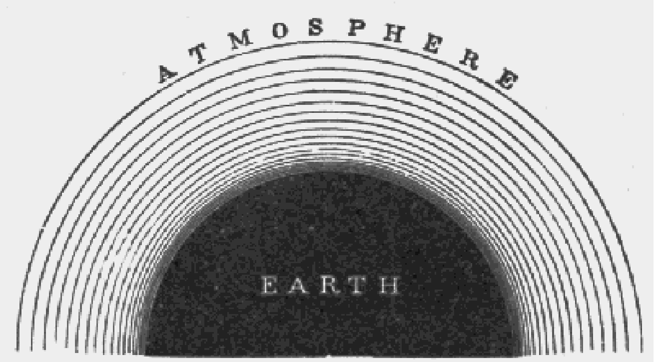
“Atmosphere”

Having now learned what air is, the next question which presents itself is, Why does it stay round our earth? You will remember that all the little atoms of a gas are trying to fly away from each other, so that if I open a bottle of perfume or slice an onion the atoms soon reach you at the farther end of the room, and you can smell the gas. Why, then, do not all the atoms of oxygen and nitrogen fly away from our earth into space, and leave us without any air?

Ah! here you must look for another of our invisible forces. Have you forgotten our giant force, "gravitation," which draws things together from a distance? This force draws together the earth and the atoms of oxygen and nitrogen; and as the earth is very big and heavy, and the atoms of air are light and easily moved, they are drawn down to the earth and held there by gravitation. But for all that, the atmosphere does not leave off trying to fly away; it is always pressing upwards and outwards with all its might, while the earth is doing its best to hold it down.

The effect of this is, that near the earth, where the pull downward is very strong, the air-atoms are drawn very closely together, because gravitation gets the best in the struggle. But as we get farther and farther from the earth, the pull downward becomes weaker, and then the air-atoms spring farther apart, and the air becomes thinner. Suppose that the lines in this diagram represent layers of air. Near the earth we have to represent them as lying closely together, but as they recede from the earth they are also farther apart.

Fig. 11.



But the chief reason why the air is thicker or denser nearer the earth, is because the upper layers press it down. If you have a heap of papers lying one on the top of the other, you know that those at the bottom of the heap will be more closely pressed together than those above, and just the same is the case with the atoms of the air. Only there is this difference, if the papers have lain for some time, when you take the top ones off, the under ones remain close together. But it is not so with the air, because air is elastic, and the atoms are always trying to fly apart, so that directly you take away the pressure they spring up again as far as they can.

You can observe this in an old-fashioned pop-gun toy. If you push the cork in very tight, and then force the piston slowly inwards, you can compress the air a good deal. Now you are forcing the atoms nearer and nearer together, but at last they rebel so strongly against being more crowded that the cork cannot resist their pressure. Out it flies, and the atoms spread themselves out comfortably again in the air all around them. Now, just as one presses the air together in the pop-gun, so the atmosphere high up above the earth presses on the air below and keeps the atoms closely packed together. And in this case the atoms cannot force back the air above them as they did the cork in the pop-gun; they are obliged to submit to being pressed together.

4.

from THE AERIAL OCEAN IN WHICH WE LIVE

“How Big Is the Atmosphere”

A short distance from the earth, at the top of a high mountain, the air becomes lighter, because it has less weight of atmosphere above it, and people who go up in balloons often have great difficulty in breathing, because the air is so thin and light. In 1804 a Frenchman, named Gay-Lussac, went up four miles and a half in a balloon, and brought down some air; and he found that it was much less heavy than the same quantity of air taken close down to the earth, showing that it was much thinner, or rarer, as it is called; and when, in 1862, Mr. Glaisher and Mr. Coxwell went up five miles and a half, Mr. Glaisher's veins began to swell, and his head grew dizzy, and he fainted. The air was too thin for him to breathe enough in at a time, and it did not press heavily enough on the drums of his ears and the veins of his body. He would have died if Mr. Coxwell had not quickly let off some of the gas in the balloon, so that it sank down into denser air.

And now comes another very interesting question. If the air gets less and less dense as it is farther from the earth, where does it stop altogether?

[Arabella Buckley lived a long time ago before we had the technology to answer scientific inquiry the way we do now. A modern scientist addresses this question in this excerpt from Eric Sloane’s Weather Book.]

> As soon as a weather student learns that the surface of the earth is above his head, he wants to know how far upward this atmospheric sea extends. Oddly enough, there is no answer, for air things out gradually into nothingness. The thinning of air with altitude is so very gradual that there is no particular height where you can say, “Here air ends and space begins.” The appreciable atmosphere, however, is said to extend for about twenty-five miles. By “appreciable” I don’t mean “livable,” I mean “measurable.” The very sea-bottom of the atmosphere

> is the only truly appreciable part for us, because that is the only place where we find life. About ten feet down in the solid earth and about three miles overhead, all known life ceases to be. We are confined to this comparatively thin film of our atmospheric deep sea.

We cannot go up to find out, because we should die long before we reached the limit; and for a long time we had to guess about how high the atmosphere probably was, and it was generally supposed not to be more than fifty miles. But lately, some curious bodies, which we should have never suspected would be useful to us in this way, have let us into the secret of the height of the atmosphere. These bodies are the meteors, or falling stars.

Most people, at one time or another, have seen what looks like a star shoot right across the sky, and disappear. On a clear starlit night you may often see one or more of these bright lights flash through the air; for one falls on an average in every twenty minutes, and on the nights of August 9th and November 13th there are numbers in one part of the sky. These bodies are not really stars; they are simply stones or lumps of metal flying through the air, and taking fire by clashing against the atoms of oxygen in it. There are great numbers of these masses moving round and round the sun, and when our earth comes across their path, as it does especially in August and November, they dash with such tremendous force through the atmosphere that they grow white-hot, and give out light, and then disappear, melted into vapour. Every now and then one falls to the earth before it is all melted away, and thus we learn that these stones contain tin, iron, sulphur, phosphorus, and other substances.

It is while these bodies are burning that they look to us like falling stars, and when we see them we know that they must be dashing against our atmosphere. Now if two people stand a certain known distance, say fifty miles, apart on the earth, and observe these meteors and the direction in which they each see them fall, they can calculate (by means of the angle between the two directions) how high they are above them when they first see them, and at that moment they must have struck against the atmosphere, and even travelled some way through it, to become white-hot. In this way we have learnt that meteors burst into light at least 100 miles above the surface of the earth, and so the atmosphere must be more than 100 miles high.

5.

from THE AERIAL OCEAN IN WHICH WE LIVE

"Air Pressure"

Our next question is as to the weight of our aerial ocean. You will easily understand that all this air weighing down upon the earth must be very heavy, even though it grows lighter as it ascends. The atmosphere does, in fact, weigh down upon land at the level of the sea as much as if a 15-pound weight were put upon every square inch of land. I have a little piece of linen paper that measures exactly a square inch, and as it lies on the table, it is bearing a weight of 15 lbs. on its surface. But how, then, comes it that I can lift it so easily? Why am I not conscious of the weight?

To understand this you must give all your attention for it is important and at first not very easy to grasp. You must remember, in the first place, that the air is heavy because it is attracted to the earth, and in the second place, that since air is elastic all the atoms of it are pushing upwards against this gravitation. And so, at any point in air, as for instance the place where the paper now is as I hold it up, I feel no pressure, because exactly as much as gravitation is pulling the air down, so much elasticity is resisting and pushing it up. So the pressure is equal upwards, downwards, and on all sides, and I can move the paper with equal ease any way.

Even if I lay the paper on the table this is still true, because there is always some air under it. If, however, I could get the air quite away from one side of the paper, then the pressure on the other side would show itself. I can do this by simply wetting the paper and letting it fall on the table, and the water will prevent any air from getting under it. Now see! if I try to lift it by the thread in the middle, I have great difficulty, because the whole 15 pounds' weight of the atmosphere is pressing it down. A still better way of making the experiment is with a piece of leather, such as the boys often amuse themselves with in the streets. This piece of leather has been well soaked. If I drop it on the floor, it requires all my strength to pull it up! I can drop it on a stone weight, and so heavily is it pressed down upon it by the atmosphere that I can lift the weight without its breaking away from it.

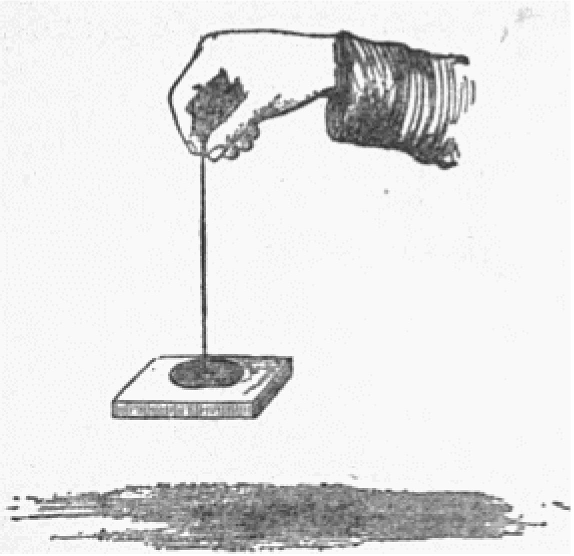


Fig. 13.—Soaked leather lifting a stone paperweight.

Have you ever tried to pick limpets off a rock? [Or for our modern readers, pull a suction cup off of a smooth surface?] If so, you know how tight they cling. The limpet clings to the rock just in the same way as this leather does to the stone; the little animal exhausts the air inside its shell, and then it is pressed against the rock by the whole weight of the air above.

Perhaps you will wonder how it is that if we have a weight of 15 lbs. pressing on every square inch of our bodies, it does not crush us. And, indeed, it amounts on the whole to a weight of about 15 tons upon the body of a grown man. It would crush us if it were not that there are gases and fluids inside our bodies which press outwards and balance the weight so that we do not feel it at all.

This is why Mr. Glaisher's veins swelled and he grew giddy in thin air. The gases and fluids inside his body were pressing outwards as much as when he was below, but the air outside did not press so heavily, and so all the natural condition of his body was disturbed.

I hope we now realize how heavily the air presses down upon our earth, but it is equally necessary to understand how, being elastic, it also presses upwards; and we can prove this by a simple experiment. I fill this tumbler with water, and keeping a piece of card firmly pressed against it, I turn the whole upside-down. When I now take my hand away you would naturally expect the card to fall, and the water to be spilt. But no! the card remains as if glued to the tumbler, kept there entirely by the air pressing upwards against it.

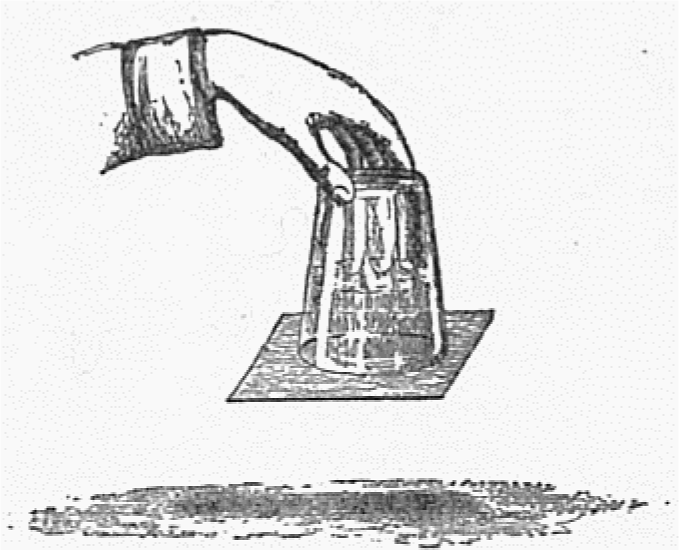


Fig. 14.—Inverted tumbler of water with a card kept against it by atmospheric pressure.

6.

from THE AERIAL OCEAN IN WHICH WE LIVE

"How We Weigh Air"

And now we are almost prepared to understand how we can weigh the invisible air. One more experiment first. I have here what is called a U tube, because it is shaped like a large U. I pour some water in it till it is about half full, and you will notice that the water stands at the same height in both arms of the tube (A, Fig. 15), because the air presses on both surfaces alike. Putting my thumb on one end I tilt the tube carefully, so as to make the water run up to the end of one arm, and then turn it back again (B, Fig. 15). But the water does not now return to its even position, it remains up in the arm on which my thumb rests. Why is this? Because my thumb keeps back the air from pressing at that end, while the whole weight of the atmosphere rests on the water at c. And so we learn that not only has the atmosphere real weight but we can see the effects of this weight by making it balance a column of water or any other liquid. In the case of the wetted leather we felt the weight of the air, here we see its effects.

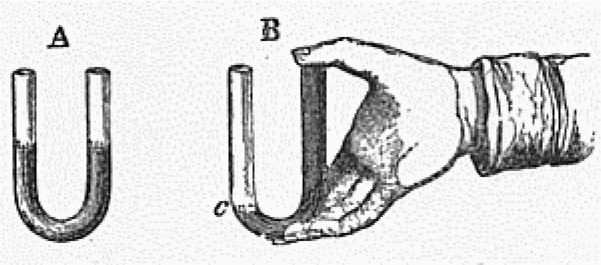


Fig. 15.

A, Water in a U tube under natural pressure of air.

B, Water kept in one arm of the tube by pressure of the air being at the open end only at c.

We are now able to form some picture of our aerial ocean. We can imagine the active atoms of oxygen floating in the sluggish nitrogen, and being used up in every candle-flame, gas-jet and fire, and in the breath of all living beings; and coming out again tied fast to atoms of carbon and making carbonic acid. Then we can turn to trees and plants, and see them tearing these two apart again, holding the carbon fast and sending the invisible atoms of oxygen bounding back again into the air, ready to recommence work. We can picture all these air-atoms, whether of oxygen or nitrogen, packed close together on the surface of the earth, and lying gradually further and further apart, as they have less weight above them, till they become so scattered that we can only detect them as they rub against the flying meteors which flash into light. We can feel this great weight of air pressing the limpet on to the rock; and we can see it pressing up the mercury in the barometer and so enabling us to measure its weight. Lastly, every breath of wind that blows past us tells us how this aerial ocean is always moving to and fro on the face of the earth; and if we think for a moment how much bad air and bad matter it must carry away, as it goes from crowded cities to be purified in the country, we can see how, in even this one way alone, it is a great blessing to us.

Yet even now we have not mentioned many of the beauties of our atmosphere. It is the tiny particles floating in the air which scatter the light of the sun so that it spreads over the whole country and into shady places. The sun's rays always travel straight forward; and in the moon, where there is no atmosphere, there is no light anywhere except just where the rays fall. But around our earth the sun-waves hit against the myriads of particles in the air and glide off them into the corners of the room or the recesses of a shady lane, and so we have light spread before us wherever we walk in the daytime, instead of those deep black shadows which we can see through a telescope on the face of the moon.

Again, it is electricity playing in the air-atoms which gives us the beautiful lightning and the grand aurora borealis, and even the twinkling of the stars is produced entirely by minute changes in the air. If it were not for our aerial ocean the stars would stare at us sternly, instead of smiling with the pleasant twinkle-twinkle which we have all learned to love as little children.

All these questions, however, we must leave for the present; only I hope you will be eager to read about them wherever you can, and open your eyes to learn their secrets. For the present we must be content if we can even picture this wonderful ocean of gas spread round our earth, and some of the work it does for us.

7.

from A DROP OF WATER ON ITS TRAVELS

“Sun, Air, and Water”

Now we are going to follow a drop of water on its travels. If I dip my finger in a basin of water and lift it up again, I bring with it a small glistening drop out of the body of water below, and hold it before you. Tell me, have you any idea where this drop has been? What changes it has undergone, and what work it has been doing during all the long ages that water has lain on the face of the earth? It is a drop now, but it was not so before I lifted it out of the basin; then it was part of a sheet of water, and will be so again if I let it fall. Again, if I were to put this basin on the stove till all the water had boiled away, where would my drop be then? Where would it go? What forms will it take before it reappears in the rain-cloud, the river, or the sparkling dew?

These are questions we are going to try to answer; and first, before we can in the least understand how water travels, we must call to mind what we have learnt about the sun and the air. We must have clearly pictured in our imagination those countless sun-waves which are forever crossing space, and especially those larger and slower undulations, the dark heat-waves; for it is these, you will remember, which force the air-atoms apart and make the air light, and it is also these which are most busy in sending water on its travels. But not these alone. The sun-waves might shake the water-drops as much as they liked, and turn them into invisible vapour, but they could not carry them over the earth if it were not for the winds and currents of that aerial ocean which bears the vapour on its bosom, and wafts it to different regions of the world.

Let us try to understand how these two invisible workers, the sun and the air, deal with the drops of water. I have here a kettle boiling over a flame, and I want you to follow minutely what is going on in it. First, in the flame, atoms of the spirit drawn up from below are clashing with the oxygen-atoms in the air. This causes heat-waves and light-waves to move rapidly all round the source of heat. The light-waves cannot pass through the kettle, but the heat-waves can, and as they enter the water inside they agitate it violently. Quickly, and still more quickly, the particles of water near the bottom of the kettle move to and fro and are shaken apart; and as they become light they rise through the colder water, letting another layer come down to be heated in its turn. The motion grows more and more violent, making the water hotter and hotter, till at last the particles of which it is composed fly asunder, and escape as invisible vapour. If this kettle were transparent you would not see any steam above the water, because it is in the form of an invisible gas. But as the steam comes out of the mouth of the kettle you see a cloud. Why is this? Because the vapour is chilled by coming out into the cold air, and its particles are drawn together again into tiny, tiny drops of water, to which Dr. Tyndall has given the suggestive name of water-dust. If you hold a plate over the steam you can catch these tiny drops, though they will run into one another almost as you are catching them.

The clouds you see floating in the sky are made of exactly the same kind of water-dust as the cloud from the kettle, and I wish to show you that this is also really the same as the invisible steam within the kettle. I will do so by an experiment suggested by Dr. Tyndall. Here is another open flame, which I will hold under the cloud of steam—see! the cloud disappears! As soon as the water-dust is heated the heat-waves scatter it again into invisible particles, which float away into the room. Even without the spirit-lamp, you can convince yourself that water-vapour may be invisible; for close to the mouth of the kettle you will see a short blank space before the cloud begins. In this space there must be steam, but it is still so hot that you cannot see it; and this proves that heat-waves can so shake water apart as to carry it away invisibly right before your eyes.

8.
from A DROP OF WATER ON ITS TRAVELS
“Rain I”

Now, although we never see any water travelling from our earth up into the skies, we know that it goes there, for it comes down again in rain, and so it must go up invisibly. But where does the heat come from which makes this water invisible? Not from below, as in the case of the kettle, but from above, pouring down from the sun. Wherever the sun-waves touch the rivers, ponds, lakes, seas, or fields of ice and snow upon our earth, they carry off invisible water-vapour. They dart down through the top layers of the water, and shake the water-particles forcibly apart; and in this case the drops fly asunder more easily and before they are so hot, because they are not kept down by a great weight of water above, as in the kettle, but find plenty of room to spread themselves out in the gaps between the air-atoms of the atmosphere.

Can you imagine these water-particles, just above any pond or lake, rising up and getting entangled among the air-atoms? They are very light, much lighter than the atmosphere; and so, when a great many of them are spread about in the air which lies just over the pond, they make it much lighter than the layer of air above, and so help it to rise, while the heavier layer of air comes down ready to take up more vapour.

In this way the sun-waves and the air carry off water every day, and all day long, from the top of lakes, rivers, pools, springs, and seas, and even from the surface of ice and snow. Without any fuss or noise or sign of any kind, the water of our earth is being drawn up invisibly into the sky.

It has been calculated that in the Indian Ocean three-quarters of an inch of water is carried off from the surface of the sea in one day and night; so that as much as 22 feet, or a depth of water about twice the height of an ordinary room, is silently and invisibly lifted up from the whole surface of the ocean in one year. It is true this is one of the hottest parts of the earth, where the sun-waves are most active; but even in our own country many feet of water are drawn up in the summer-time.

What, then, becomes of all this water? Let us follow it as it struggles upwards to the sky. We see it in our imagination first carrying layer after layer of air up with it from the sea till it rises far above our heads and above the highest mountains. But now, call to mind what happens to the air as it recedes from the earth. Do you not remember that the air-atoms are always trying to fly apart, and are only kept pressed together by the weight of air above them? Well, as this water-laden air rises up, its particles, no longer so much pressed together, begin to separate, and in so doing they use up part of the heat which they carried up from the earth, and thus the air becomes colder. Then you know at once what must happen to the invisible vapour,—it will form into tiny water-drops, like the steam from the kettle. And so, as the air rises and becomes colder, the vapour gathers into visible masses, and we can see it hanging in the sky, and call it clouds. When these clouds are highest they are about ten miles from the earth, but when they are made of heavy drops and hang low down, they sometimes come within a mile of the ground.

Look up at the clouds today, and think that the water of which they are made has all been drawn up invisibly through the air. Not, however, necessarily here in London, for we have already seen that air travels as wind all over the world, rushing in to fill spaces made by rising air wherever they occur, and so these clouds may be made of vapour collected in the Mediterranean, or in the Gulf of Mexico off the coast of America, or even, if the wind is from the north, of chilly particles gathered from the surface of Greenland ice and snow, and brought here by the moving currents of air. Only, of one thing we may be sure, that they come from the water of our earth.

9.

from A DROP OF WATER ON ITS TRAVELS

“Rain II”

Sometimes, if the air is warm, these water-particles may travel a long way without ever forming into clouds; and on a hot, cloudless day the air is often very full of invisible vapour. Then, if a cold wind comes sweeping along, high up in the sky, and chills this vapour, it forms into great bodies of water-dust clouds, and the sky is overcast. At other times clouds hang lazily in a bright sky, and these show us that just where they are the air is cold and turns the invisible vapour rising from the ground into visible water-dust, so that exactly in those spaces we see it as clouds. Such clouds form often on a warm, still summer's day, and they are shaped like masses of wool, ending in a straight line below. They are not merely hanging in the sky, they are really resting upon a tall column of invisible vapour which stretches right up from the earth; and that straight line under the clouds marks the place where the air becomes cold enough to turn this invisible vapour into visible drops of water.

And now, suppose that while these or any other kind of clouds are overhead, there comes along either a very cold wind, or a wind full of vapour. As it passes through the clouds, it makes them very full of water, for, if it chills them, it makes the water-dust draw more closely together; or, if it brings a new load of water-dust, the air is fuller than it can hold. In either case a number of water-particles are set free, and our fairy force "cohesion" seizes upon them at once and forms them into large water-drops. Then they are much heavier than the air, and so they can float no longer, but down they come to the earth in a shower of rain.

There are other ways in which the air may be chilled, and rain made to fall, as, for example, when a wind laden with moisture strikes against the cold tops of mountains. Thus the Khasia Hills in India, which face the Bay of Bengal, chill the air which crosses them on its way from the Indian Ocean. The wet winds are driven up the sides of the hills, the air expands, and the vapour is chilled, and forming into drops, falls in torrents of rain. Sir J. Hooker tells us that as much as 500 inches of rain fell in these hills in nine months. That is to say, if you could measure off all the ground over which the rain fell, and spread the whole nine months' rain over it, it would make a lake 500 inches, or more than 40 feet deep! You will not be surprised that the country on the other side of these hills gets hardly any rain, for all the water has been taken out of the air before it comes there. Again for example in England, the wind comes to Cumberland and Westmoreland over the Atlantic, full of vapour, and as it strikes against the Pennine Hills it shakes off its watery load; so that the lake district is the most rainy in England, with the exception perhaps of Wales, where the high mountains have the same effect.

In this way, from different causes, the water of which the sun has robbed our rivers and seas, comes back to us, after it has travelled to various parts of the world, floating on the bosom of the air. But it does not always fall straight back into the rivers and seas again, a large part of it falls on the land, and has to trickle down slopes and into the earth, in order to get back to its natural home, and it is often caught on its way before it can reach the great waters.

10.

from A DROP OF WATER ON ITS TRAVELS

“Screen of Vapor”

Go to any piece of ground which is left wild and untouched, you will find it covered with grass, weeds, and other plants; if you dig up a small plot you will find innumerable tiny roots creeping through the ground in every direction. Each of these roots has a sponge-like mouth by which the plant takes up water. Now, imagine rain-drops falling on this plot of ground and sinking into the earth. On every side they will find rootlets thirsting to drink them in, and they will be sucked up as if by tiny sponges, and drawn into the plants, and up the stems to the leaves. Here they are worked up into food for the plant, and only if the leaf has more water than it needs, some drops may escape at the tiny openings under the leaf, and be drawn up again by the sun-waves as invisible vapour into the air.

Again, much of the rain falls on hard rock and stone, where it cannot sink in, and then it lies in pools till it is shaken apart again into vapour and carried off in the air. Nor is it idle here, even before it is carried up to make clouds. We have to thank this invisible vapour in the air for protecting us from the burning heat of the sun by day and intolerable frost by night.

Let us for a moment imagine that we can see all that we know exists between us and the sun. First, we have the fine ether across which the sun’s rays travel, beating down upon our earth with immense force, so that in the sandy desert they are like a burning fire. Then we have the coarser atmosphere of oxygen and nitrogen atoms hanging in this ether, and bending the minute sun-waves out of their direct path. But they do very little to hinder them on their way, and this is why in very dry countries the sun's heat is so intense. The rays beat down mercilessly, and nothing opposes them. Lastly, in damp countries we have the larger but still invisible particles of vapour hanging about among the air-atoms. Now, these watery particles, although they are very few (only about one twenty-fifth part of the whole atmosphere), do hinder the sun-waves. For they are very greedy of heat, and though the light-waves pass easily through them, they catch the heat-waves and use them to help themselves to expand. And so, when there is invisible vapour in the air, the sunbeams come to us deprived of some of their heat-waves, and we can remain in the sunshine without suffering from the heat.

This is how the water-vapour shields us by day, but by night it is still more useful. During the day our earth and the air near it have been storing up the heat which has been poured down on them, and at night, when the sun goes down, all this heat begins to escape again. Now, if there were no vapour in the air, this heat would rush back into space so rapidly that the ground would become cold and frozen even on a summer's night, and all but the most hardy plants would die. But the vapour which formed a veil against the sun in the day, now forms a still more powerful veil against the escape of the heat by night. It shuts in the heat-waves, and only allows them to make their way slowly upwards from the earth—thus producing for us the soft, balmy nights of summer and preventing all life being destroyed in the winter.

Perhaps you would scarcely imagine at first that it is this screen of vapour which determines whether or not we shall have dew upon the ground. Have you ever thought why dew forms, or what power has been at work scattering the sparkling drops upon the grass? Picture to yourself that it has been a very hot summer's day, and the ground and the grass have been well warmed, and that the sun goes down in a clear sky without any clouds. At once the heat-waves which have been stored up in the ground, bound back into the air, and here some are greedily absorbed by the vapour, while others make their way slowly upwards. The grass, especially, gives out these heat-waves very quickly, because the blades, being very thin, are almost all surface. In consequence of this they part with their heat more quickly than they can draw it up from the ground, and become cold. Now, the air lying just above the grass is full of invisible vapour, and the cold of the blades, as it touches them, chills the water-particles, and they are no longer able to hold apart, but are drawn together into drops on the surface of the leaves.

We can easily make artificial dew for ourselves. I have here a bottle of ice which has been kept outside the window. When I bring it into the warm room a mist forms rapidly outside the bottle. This mist is composed of water-drops, drawn out of the air of the room, because the cold glass chilled the air all round it, so that it gave up its invisible water to form dew-drops. Just in this same way the cold blades of grass chill the air lying above them, and steal its vapour.

But try the experiment, some night when a heavy dew is expected, of spreading a thin piece of cloth over some part of the grass, supporting it at the four corners with pieces of stick so that it forms an awning. Though there may be plenty of dew on the grass all round, yet under this awning you will find scarcely any. The reason of this is that the muslin checks the heat-waves as they rise from the grass, and so the grass-blades are not chilled enough to draw together the water-drops on their surface. If you walk out early in the summer mornings and look at the fine cobwebs flung across the hedges, you will see plenty of drops on the cobwebs themselves sparkling like diamonds; but underneath on the leaves there will be none, for even the delicate cobweb has been strong enough to shut in the heat-waves and keep the leaves warm.

Again, if you walk off the grass onto the gravel path, you find no dew there. Why is this? Because the stones of the gravel can draw up heat from the earth below as fast as they give it out, and so they are never cold enough to chill the air which touches them. On a cloudy night also you will often find little or no dew even on the grass. The reason of this is that the clouds give back heat to the earth, and so the grass does not become chilled enough to draw the water-drops together on its surface.

But after a hot, dry day, when the plants are thirsty and there is little hope of rain to refresh them, then they are able in the evening to draw the little drops from the air and drink them in before the rising sun comes again to carry them away.

11.

from A DROP OF WATER ON ITS TRAVELS

“What Are Crystals?”

But our rain-drop undergoes other changes more strange than these. Till now we have been imagining it to travel only where the temperature is moderate enough for it to remain in a liquid state as water. But suppose that when it is drawn up into the air it meets with such a cold blast as to bring it to the freezing point. If it falls into this blast when it is already a drop, then it will freeze into a hailstone, and often on a hot summer's day we may have a severe hailstorm, because the rain-drops have crossed a bitterly cold wind as they were falling, and have been frozen into round drops of ice.

But if the water-vapour reaches the freezing air while it is still an invisible gas, and before it has been drawn into a drop, then its history is very different. The ordinary force of cohesion has then no power over the particles to make them into watery globes, but its place is taken by the fairy process of "crystallization," and they are formed into beautiful white flakes, to fall in a snow-shower. I want you to picture this process to yourselves, for if once you can take an interest in the wonderful power of nature to build up crystals, you will be astonished how often you will meet with instances of it, and what pleasure it will add to your life.

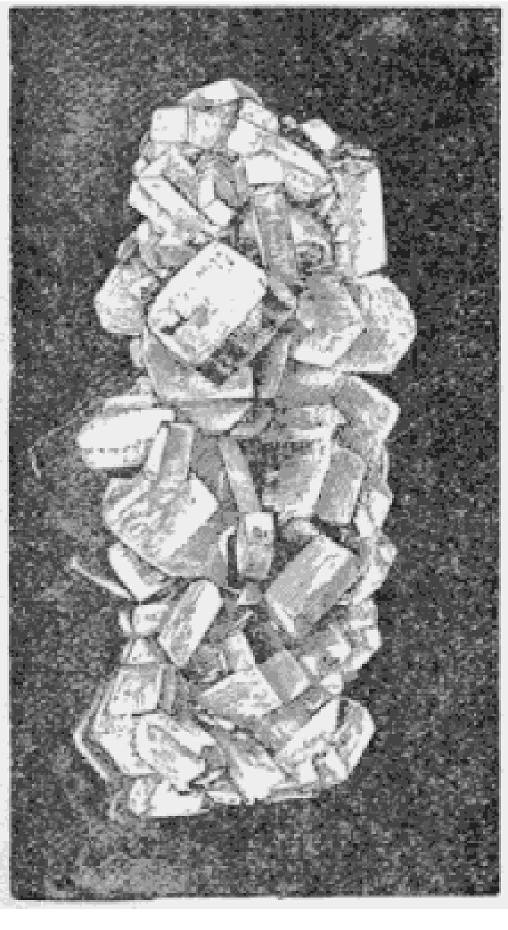


Fig. 20.

A piece of sugar-candy, photographed of the natural size.

The particles of nearly all substances, when left free and not hurried, can build themselves into crystal forms. If you melt salt in water and then let all the water evaporate slowly, you will get salt-crystals;—beautiful cubes of transparent salt all built on the same pattern. The same is true of sugar; and if you will look at the spikes of an ordinary stick of sugar-candy, such as is pictured here, you will see the kind of crystals which sugar forms. You may even pick out such shapes as these from the common crystallized brown sugar in the sugar basin, or see them with a magnifying glass on a lump of white sugar.

But it is not only easily melted substances such as sugar and salt which form crystals. The beautiful stalactite grottos are all made of crystals of lime. Diamonds are crystals of carbon, made inside the earth. Rock-crystals, which you know probably under the name of Irish diamonds, are crystallized quartz; and so, with slightly different colourings, are agates, opals, jasper, onyx, cairngorms, and many other precious stones. Iron, copper, gold, and sulphur, when melted and cooled slowly build themselves into crystals, each of their own peculiar form, and we see that there is here a wonderful order, such as we should never have dreamt of, if we had not proved it. If you possess a microscope you may watch the growth of crystals yourself by melting some common powdered nitre in a little water till you find that no more will melt in it. Then put a few drops of this water on a warm glass slide and place it under the microscope. As the drops dry you will see the long transparent needles of nitre forming on the glass, and notice how regularly these crystals grow, not by taking food inside like living beings, but by adding particle to particle on the outside evenly and regularly.

12.

from A DROP OF WATER ON ITS TRAVELS

“Why Do Crystals Form”

Can we form any idea why the crystals build themselves up so systematically? Dr. Tyndall says we can, and I hope by the help of these small bar magnets to show you how he explains it. These little pieces of steel I have lying on this white cardboard have been rubbed along a magnet until they have become magnets themselves, and I can attract and lift up a needle with any one of them. But if I try to lift one bar with another, I can only do it by bringing certain ends together. I have tied a piece of red thread round one end of each of the magnets, and if I bring two red ends together they will not cling together but roll apart.

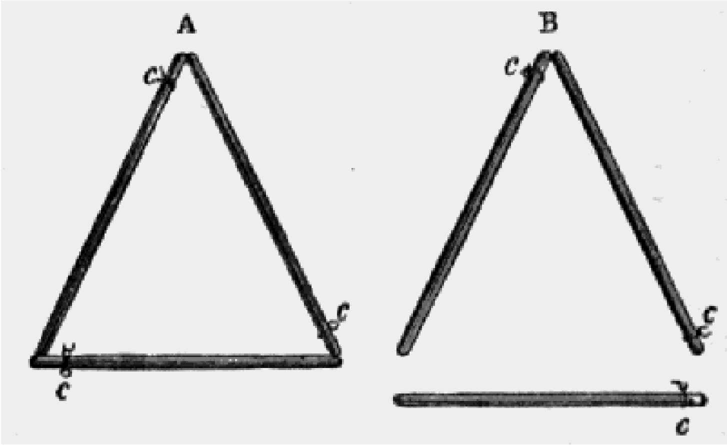


Fig. 21.
Bar magnets attracting and repelling each other.
c, Cotton tied round the north pole of the magnet.

If, on the contrary, I put a red end against an end where there is no thread, then the two bars cling together. This is because every magnet has two poles or points which are exactly opposite in character. One of these is called the north pole of the magnet, because, if the rod hangs freely, that end will point to the north, and the other is the south pole, pointing to the south. Now, when I bring two red ends, that is, two north poles together, they drive each other away. See! the magnet I am not holding runs away from the other. The same will happen if I bring two south poles together. But if I bring a red end and a black end, that is, a north pole and a south pole together, then they are attracted and cling. I will make a triangle (A, Fig. 21) in which a black end and a red end always come together, and you see the triangle holds together. But now if I take off the lower bar and turn it (B, Fig. 21) so that two red ends and two black ends come together, then this bar actually rolls back from the others down the cardboard. If I were to break these bars into a thousand pieces, each piece would still have two poles, and if they were scattered about near each other in such a way that they were quite free to move, they would arrange themselves always so that two different poles came together.

Now picture to yourselves that all the particles of those substances which form crystals have poles like our magnets, then you can imagine that when the heat which held them apart is withdrawn and the particles come very near together, they will arrange themselves according to the attraction of their poles and so build up regular and beautiful patterns.

13.

from A DROP OF WATER ON ITS TRAVELS

“Snow Crystals”

So, if we could travel up to the clouds where this fairy power of crystallization is at work, we should find the particles of water-vapour in a freezing atmosphere being built up into minute solid crystals of snow. If you go out after a snow-shower and search carefully, you will see that the snow-flakes are not mere lumps of frozen water, but beautiful six-pointed crystal stars, so white and pure that when we want to speak of anything being spotlessly white, you say that it is "white as snow." Some of these crystals are simply flat slabs with six sides, others are stars[Pg 90] with six rods or spikes springing from the centre, others with six spikes each formed like a delicate fern. No less than a thousand different forms of delicate crystals have been found among snow-flakes, but though there is such a great variety, yet they are all built on the six-sided and six-pointed plan, and are all rendered dazzlingly white by the reflection of the light from the faces of the crystals and the tiny air-bubbles built up within them. This, you see, is why, when the snow melts, you have only a little dirty water in your hand; the crystals are gone and there are no more air-bubbles held prisoners to act as looking-glasses to the light. Hoar-frost is also made up of tiny water-crystals, and is nothing more than frozen dew hanging on the blades of grass and from the trees.

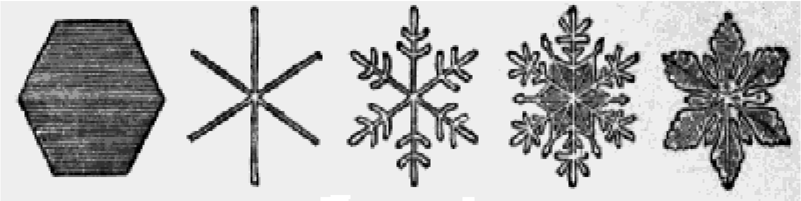


Fig. 22.—Snow-crystals.

But how about ice? Here, you will say, is frozen water, and yet we see no crystals, only a clear transparent mass. Here, again, Dr. Tyndall helps us. He says (and as I have proved it true, so may you for yourselves, if you will) that if you take a magnifying glass, and look down on the surface of ice on a sunny day, you will see a number of dark, six-sided stars, looking like flattened flowers, and in the centre of each a bright spot. These flowers, which are seen when the ice is melting, are our old friends the crystal stars[Pg 91] turning into water, and the bright spot in the middle is a bubble of empty space, left because the watery flower does not fill up as much room as the ice of the crystal star did.

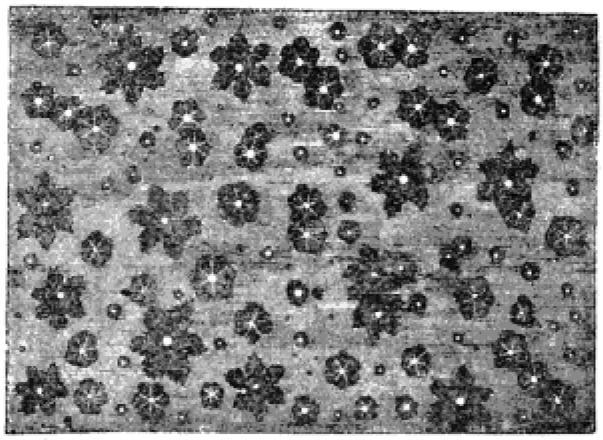


Fig. 23.—Water-flowers in melting ice.—Tyndall.

And this leads us to notice that ice always takes up more room than water, and that this is the reason why our water-pipes burst in severe frosts; for as the water freezes it expands with great force, and the pipe is cracked, and then when the thaw comes on, and the water melts again, it pours through the crack the ice has made.

It is not difficult to understand why ice should take more room; for we know that if we were to try to arrange bricks end to end in star-like shapes, we must leave some spaces between, and could not pack them so closely as if they lay side by side. And so, when this giant force of crystallization constrains the atoms of frozen water to grow into star-like forms, the solid mass must fill more room than the liquid water, and when the star melts, this space reveals itself to us in the bright spot of the centre