THE WONDER BOOK OF THE ATMOSPHERE

EDWIN J. HOUSTON

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BY

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CHAPTER I

THE SHAPE, HEIGHT, AND COMPOSITION OF THE ATMOSPHERE

The word "atmosphere" means literally a globe or sphere of air. If, however, you have the idea that the atmosphere, or the ocean of air that surrounds our earth, has the shape of a huge sphere you will be mistaken, for our atmosphere is only a thin shell or layer of air, the lower surface of which takes the shape of the earth's surface, on which it rests, while even its upper surface is not that of a true sphere, but of an *oblate spheroid.*

A spheroid is a ball or sphere that is slightly flattened at its opposite sides. When a spheroid rotates, or spins like a top, the diameter on which it turns is called its *axis.* In Figs. 1 and 2 two different kinds of spheroids are represented. In that shown in Fig. 1, the diameter AB, on which the spheroid is assumed to rotate, is shorter than the diameter CD; or, as we would say in geography, the *polar diameter* AB, is shorter than the *equatorial diameter* CD. Such a spheroid is called an *oblate spheroid.*

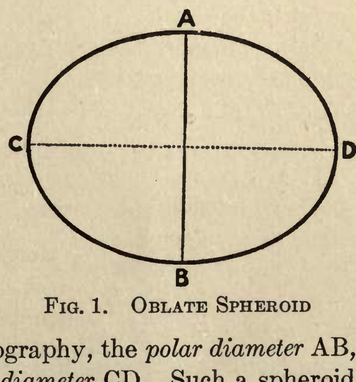


FIG. 1. OBLATE SPHEROID

Fig. 2, represents a spheroid in which the axis or polar diameter AB, is longer than the equatorial diameter CD. Such a spheroid is called a *prolate spheroid.*

We do not know accurately the height of the earth's atmosphere. We are certain, however, that this height cannot exceed a certain value; for, we know just how fast the earth turns or rotates on its axis, and can, therefore, calculate its centrifugal force, or the force in a spinning body that tends to throw things off from its surface. Now, it can be shown, in the case of our earth, that as soon as the centrifugal force in the equatorial regions reaches a given value, the particles of air in the atmosphere that extend a certain height above the earth's surface, would no longer be able to remain on the earth, but would be thrown off into space, never again to return. In this manner by making a proper allowance for the decrease in weight, that all bodies undergo by reason of their increased distance above the surface of the earth, it is possible to show that the height of the atmosphere cannot be greater than 21,000 miles above the surface of the earth, since, at such a distance, no particles of air could remain on the earth.

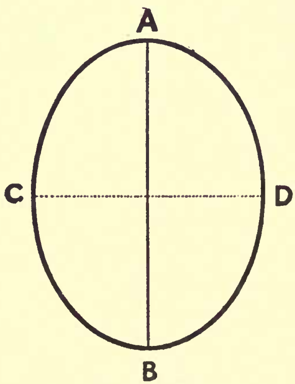


FIG. 2. PROLATE SPHEROID

It is by no means easy to determine the height of the earth's atmosphere; for we live at the bottom of this mass of air, and, since air is transparent, we cannot see its upper surface.

Fortunately, however, there is an instrument that enables us roughly to measure the height of the atmosphere from the amount of pressure the air exerts on the earth's surface. This instrument is called a *barometer* and will afterwards be described in full. By its use, by noting the decrease in the pressure the air exerts at different heights above the level of the sea, it is possible to make a fairly close estimate of the height of the atmosphere, or at least the distance the greater portion of it lies above the earth's surface. Calculations made in this way seem to show that the least height above the level of the sea it is possible for the atmosphere to have, is somewhere between forty-five and fifty miles. It is almost certain, however, that a small portion of our atmosphere exists above these heights, and, although the distance to which it extends may be very great, yet the weight of this portion must be extremely small.

While, therefore, the height of the atmosphere cannot exceed 21,000 miles above the level of the sea, its height must at least be as great as forty-five to fifty miles above such surface.

There is another way in which the height of the atmosphere can be calculated, and this is by the duration of *twilight*. Had our earth no atmosphere whatever, daylight would not begin until the sun rose above the horizon, and night would set in the moment the sun sank below it. On the other hand, if our atmosphere extended for an unlimited distance above the earth's surface there would be no night; for, no matter where the sun might be, some of its light would be reflected to all parts of the earth's surface from some of its different layers. Now twilight increases the length of the day to an extent depending on the height of the atmosphere.

After the sun has set, its rays light up the air over our heads and this lighted air reflects or throws the light down on the earth, so that the earth's surface remains lighted long after the sun has set, and begins to receive the light long before the sun has risen.

While the duration of twilight varies in different parts of the earth, yet the night does not actually begin until the sun has sunk about 18° below the horizon.

The astronomer, Young, shows that on March 1st, and

October 12th, in lat. 40° N., it takes the sun about ninety minutes to reach this distance of 18° below the horizon, after it has just sunk below it, while on the 20th of June, it requires more than two hours for the sun to reach this position. In latitudes higher than 50°, where the lengths of daylight are the greatest, twilight never quite disappears, even at midnight. On the other hand, in elevated regions, such as in the high mountain districts of Peru, the length of twilight never exceeds thirty minutes.

Calculated in the different ways above pointed out the height of our atmosphere may, perhaps, be taken as about 200 miles above the level of the sea. It most probably extends, however, in a very tenuous condition for considerable distances above this height. So far as its weight is concerned the greater part of the atmosphere lies within a few miles of the earth's surface.

In the higher regions of our atmosphere the air must be exceedingly rare. Indeed, there is so small a quantity of air present that this space can almost be regarded as a vacuum. It is the passage of electric discharges through the air of these regions that produces auroras, as will be explained in the chapter on the aurora borealis. Here, too, occur most of the phenomena of meteorites, those wandering solid bodies that move so rapidly through the air that they are raised to a glowing heat by friction against the few particles of air in these regions.

It is also in the higher regions of the atmosphere that many of the phenomena of magnetism occur. Moreover, it is probably from a portion of the atmosphere, situated somewhere between its lower or grosser portions and its higher or more tenuous portions, that the electro-magnetic waves, employed in wireless telegraphy, are reflected or thrown back to the earth, and are thus confined to the lower parts of the atmosphere, and prevented from being dissipated throughout the space that lies outside our atmosphere.

Having now discussed briefly the shape and height of the atmosphere, let us inquire into its composition.

Our atmosphere consists, for the greater part, of a mixture of a number of different gaseous substances that can be divided into two great classes; i. e., the *fixed ingredients*, the relative amounts of which remain nearly the same at all times and places, and the *variable ingredients*, or those that vary considerably both at different times and at different places.

The principal fixed ingredients of the atmosphere are the elementary gases, nitrogen and oxygen. These exist in the proportion by weight of about seventy-seven parts of nitrogen and twenty-three parts of oxygen. Besides these two gases, as we shall afterwards see, a small part of what was at one time believed also to be nitrogen consists of a number of recently discovered elementary gases, known as argon, metargon, neon, xenon, and helium.

The most important of the variable constituents of the atmosphere consist of carbonic acid gas, the vapor of water, and ammonia.

Carbonic acid gas is a chemical compound of carbon and oxygen. It is carbonic acid gas that causes soda water to sparkle or fizzle and bread to rise. Carbonic acid gas is a less variable constituent of the atmosphere than water vapor, and varies in amount from five to six parts by volume in every 10,000 of air. Since there are 1,728 cubic inches in every cubic foot, if there were six parts of carbonic acid gas in every 10,000 parts of air that would be one part of carbonic acid gas in every 1,666 parts, or a little more than one in every cubic foot. Sometimes, however, the proportion of carbonic acid gas is much smaller and sometimes it is much greater than the above.

The vapor of water is a far more variable constituent. In certain parts of the earth, especially near the coasts of tropical continents and islands, there is generally a very large quantity of water vapor in the air, while in desert regions the amount of this substance is very small. Since the ability of air to hold water vapor decreases rapidly with its temperature, in the Arctic regions, where the air is very cold, the amount of water vapor is very small even near the coasts. But even in the driest parts of the earth, on the driest days, there is always a small quantity of water vapor present in the atmosphere.

It was at one time believed that the denser gases of the atmosphere, such as carbonic acid gas and oxygen, must settle down in the air so as to collect in greater quantities near the surface, thus leaving a smaller percentage of the lighter nitrogen in the higher regions. But by reason of a property of gases called *diffusion*, or the tendency of gases to thoroughly mix with one another, this is not the case. Men have gone up in balloons and brought down specimens of air from heights varying from three to four miles above the level of the sea. On studying these specimens it has been found that the same percentage of the different constituents exists in the higher as in the lower regions. Moreover, analyses of specimens of air obtained near the earth's surface, from the country, the seashore, and the crowded city, have approximately the same composition.

A small difference, however, can be detected at times in the composition of the air at different localities. The relative proportion of oxygen and nitrogen are not the same in mountains and plains, or on the seashore, as in crowded cities or assembly halls. The air of the country, of mountains, or of the seashore, contains a trifle more oxygen than the air of a crowded room, or a densely populated city.

Let us now inquire briefly as to some of the uses of the different ingredients of the atmosphere. So far as the existence of animal life is concerned, oxygen is the most important. Oxygen is necessary for the breathing of animals, the burning of coal or wood in fires, as well as the oil and gas in lamps and gas burners.

Animal life could not exist without oxygen. Decay and death are constantly going on in even the healthiest animals. The mere act of living is attended by changes in different parts of the body that are ultimately followed by the death of these parts. These dead or decaying parts either pass from the body through its principal outlets, or are carried off by the blood as it is forced by the beating of the heart through the arteries and veins. When blood is free from impurities it has a bright red color. When it is laden with impurities it has a bluish-black color. The bright red arterial blood, as it flows through the arteries, carries away with it the dead and decaying parts from the different portions of the body and thus becomes changed to the poisonous, bluish-black venous blood. Should this poisoned blood be carried to the brain it would seriously affect the health of the animal, and if it be permitted to pass for a great length of time through the brain the animal would die. But before the poisonous blood with its load of decaying matter reaches the brain it passes through the lungs. Here, by means of the oxygen of the air which the animal breathes into its lungs, these impurities are burned out and the bluish-black venous blood is thus changed to bright red arterial blood.

The substances formed by this burning or combination with the oxygen of the air consist principally of water vapor and carbonic acid gas. Consequently, while the animal breathes in oxygen from the air, it gives out very little oxygen since, practically all of it has combined with the impurities of the blood and formed carbonic acid gas and the vapor of water.

It is evident, therefore, that animals could not live without the oxygen of the air. Since the animal is thus constantly using up the oxygen of the air the amount of this gaseous substance in the atmosphere must be constantly decreasing, and, unless some provision had been made for this loss, animal life would soon cease on the earth by the removal of all the oxygen from its atmosphere. Let us see how the loss of this oxygen is made up for by the presence of plant life.

The carbonic acid gas of the atmosphere is necessary for the existence of plant life. The leaves of a plant act as its lungs. They breathe in carbonic acid gas from the air. Under the influence of sunlight this carbonic acid gas is broken up into carbon and oxygen. The carbon, separated from the oxygen, is retained for the formation of the woody tissues of the plant, while the oxygen is thrown into the atmosphere. During their life, therefore, plants decrease the amount of carbonic acid gas in the air and increase its amount of oxygen. In other words, plants take in carbonic acid gas and give out oxygen. Consequently, the amount of carbonic acid gas in the air tends in this way gradually to decrease. Should it completely disappear all plant life on the earth would cease to exist.

Now a little thought will convince you that if there were only animal life on the earth it would be but a matter of time when all the oxygen of the air would be changed into carbonic acid gas by its passage through the bodies of animals, when, of course, all animal life would cease to exist. In a similar manner, if there were only plant life on the earth it would be but a matter of time when all the carbonic acid gas of the atmosphere would be decomposed by plants, its carbon retained in the plant, and its oxygen thrown out into the atmosphere. Then all plant life would cease to exist.

But God has so proportioned the earth's animal and plant life as to maintain at all times in the atmosphere the proper proportion of oxygen and carbonic acid gas. He has made animals and plants so that one cannot get along without the other. The plants need what the animals throw off; the animals need what the plants throw off. There is, therefore, in nature a repetition of the great principle of natural economy recognized by Mother Goose in a nursery rhyme:

"Jack Spratt could eat no fat,
His wife could eat no lean;
But 'twixt them both they licked the plate,
And left the platter clean."

The principal use of the nitrogen of the atmosphere is to dilute the oxygen. If our atmosphere consisted wholly of oxygen all combustion would be very rapid. Animal life would be intensified, but at the same time shortened. A bit of steel wire, placed inside a glass jar filled with pure oxygen, will burst into brilliant burning if started at one end in a suitable manner. If a small piece of burning phosphorus is placed inside a jar of pure oxygen as shown in Fig. 3, it will burn with wonderful brilliancy. A small taper, that has just been blown out but which still contains a small spark of fire at one end, will instantly burst into flame when introduced into a jar of oxygen.

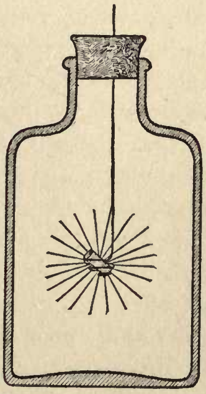


Fig. 3. Phosphorus Burning in Oxygen

When combined with hydrogen in the form of ammonia, or with oxygen as nitric acid, nitrogen forms a portion of the atmosphere that is necessary for the nourishment of plant life.

The remaining variable ingredient of the atmosphere, the vapor of water, is necessary for the existence of both plant and animal life. The absence of water, or water vapor, is always attended by the death of all plant life and the consequent production of deserts.

In addition to the above-named substances there are always present in the atmosphere a number of occasional ingredients that, generally speaking, are found in certain limited areas only. Some of the principal of these are *ozone*, *sulphurous vapors*, *sulphuretted hydrogen*, *carburetted hydrogen*, the *vapors of sulphuric*, *hydrochloric*, *and nitric acids*, *iodine and its compounds*, etc.

In addition to the above there are almost always present in the atmosphere different kinds of disease germs consisting of various microscopic forms of life known as *bacteria* or *bacilli*, etc., that may be either beneficial to both plants and animals, or may be capable of producing various diseases in them.

You may possibly think that it could not have been a very difficult matter to discover the principal ingredients of our atmosphere. It point of fact, however, it was so difficult that many years passed before even its principal gases, oxygen and nitrogen, were discovered, and it has been only of comparatively late years that the rarer elements, argon and its associates, were detected.

The ancients thought there were but four elements, earth, water, air, and fire. Naturally, therefore, in later times, the subject of combustion, or, as it was formerly called, *fire* or *inflammability*, attracted the attention of scientific men. As early as 1665, an English philosopher, Hooke, declared that there existed in the atmosphere a substance that possessed the power of permitting fire to be produced. At a somewhat later date, a German chemist, named Stahl, came to the conclusion that all combustion, both in the atmosphere and elsewhere, was due to the presence of a substance called *phlogiston*.

An effort was made to detect the presence of phlogiston by burning different combustible substances in glass vessels under water. In this way it was possible to note the changes in the volume of the air left in the vessel as well as in its properties. In this way they discovered that air employed for burning a combustible body always decreases in volume and finally becomes so changed in its properties as to be unable either to permit any further burning to go on, or animals to safely breathe it. They called the air so changed *nitre air*. It was the same as the gaseous element now called *nitrogen*.

Among the experimenters who endeavored to isolate phlogiston by burning candles in air contained in glass vessels under water was Joseph Priestley. This great chemist, in 1772, satisfied himself both as to the decrease in volume of the confined air as well as the change in its properties. These changes, however, did not surprise him. Indeed, he expected them to occur, but when he afterwards extended his experiments to plants, he was surprised to find that this deterioration and decrease in volume did not occur. On the contrary, in the presence of sunlight plants possess the power of so acting on air, that had been deteriorated by animal life that it could no longer support the flame of a candle or was no longer suitable for respiration, again acquired the power of permitting a candle to burn or animals to safely breathe it.

If you have intelligently followed what has been said concerning the different actions that animals and plants exert on air, you can understand the reason for the different changes produced in air by animals and plants; for, the animals remove all oxygen from the air so that the remaining air consists mainly of nitrogen and the carbonic acid gas that has been given out by the animals. Plants, on the contrary, simply withdraw the carbonic acid, retain its carbon, and give the oxygen back to the air.

It appears that Priestley obtained his first specimen of oxygen gas by heating, by the heat of a burning-glass held in the sunlight, a chemical substance called the *red precipitate of mercury*, consisting of mercury and oxygen. Under the influence of this heat the oxide of mercury was decomposed into metallic mercury and oxygen gas. Priestley called this gas *dephlogisticated air*, although, as we now know, it was oxygen, or, in reality, the phlogiston for which he and others had for so long a time been endeavoring to isolate.

It remained for the celebrated French chemist, Lavoisier, and at a somewhat later date, by the Swedish chemist, Scheele, to show that the gaseous substance discovered by Priestley was, in reality, one of the gases of the atmosphere.

This he did by exposing metallic mercury for a long time to the action of air until it entered into combination with something in the air and formed the red precipitate of mercury.

I think it best here to permit Lavoisier to describe this experiment:

"Taking a vessel, or long-necked tube, with a bell or globe at its extremity, containing about thirty-six cubic inches, I

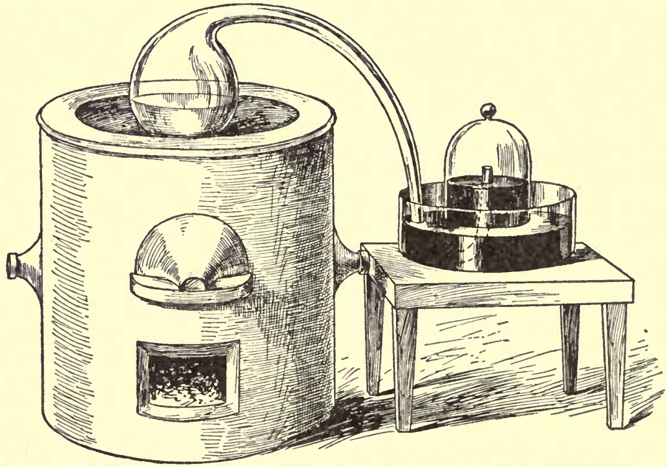


FIG. 4. LAVOISIER'S APPARATUS

bent it, so as to place it in the furnace while the extreme end of the neck was under a glass cover, which was placed in a basin of mercury (see Fig. 4). Into this vessel I poured four ounces of very pure mercury; and then, by means of a siphon, I raised the mercury to about three-quarters the height of the glass cover, and marked the level by gumming on a strip of paper. I then lighted the fire in the furnace, and kept it up incessantly for twelve days, the mercury being just sufficiently heated to boil. At the expiration of the second day, small red particles formed upon the surface of the mercury, and increased in size and number for the next four or five days, when they became stationary. At the end of the twelve days, seeing that the calcination of the mercury made no further progress, I let out the fire and set the vessels to cool. The volume of air contained in the body and neck of the vessel before the operation was fifty cubic inches; and this was reduced by evaporation to forty-two or forty-three. On the other hand, I found, upon carefully collecting the red particles out of the melted mercury, that their weight was about forty-five grains. The air which remained after this operation, and which had lost a sixth of its volume by the calcination of the mercury, was no longer fit for respiration or combustion, as animals placed in it died at once, and a candle was extinguished as if it had been plunged in water. Taking the forty-five grains of red particles, and placing them in a small glass vessel, to which was adapted an apparatus for receiving the liquids and aëriform bodies which might become separated, and having lighted the fire in the furnace, I observed that the more the red matter became heated, the deeper became its color. When the vessel approached incandescence, the red matter commenced to become smaller, and in a few minutes had quite disappeared; and at the same time forty-one and a half grains of mercury became condensed in the small receiver; and from seven to eight cubic inches of an elastic fluid, better adapted than the air of the atmosphere to supply the respiration of animals and combustion, passed under the glass cover. From the consideration of this experiment, we see that the mercury, while it is being calcined, absorbs the only portion of the air fit for respiration, or, to speak more correctly, the base of this portion; and the rest of the air which remains is unable to support combustion or undergo respiration. Atmospheric air is, therefore, composed of two elastic fluids of different, and even opposite, natures."

It was, therefore, Lavoisier and Scheele who discovered the oxygen of the atmosphere.

Before closing this chapter on the composition of the atmosphere it may be interesting to note the manner in which the rare elementary substances, argon, neon, krypton, xenon, and helium were detected. Despite the many researches that were made on the chemical composition of the atmosphere, these substances remained undetected until 1894. They are all substances that so closely resemble nitrogen in their properties that up to this time they had been mistaken for nitrogen itself.

It is difficult at first thought to understand how it was possible, since we are constantly taking argon and its associated gases into our bodies through the lungs, that they should have remained undiscovered until 1894. This failure, however, can be understood when it is known that they not only exist in very small quantities in the atmosphere, but are also exceedingly inert. Indeed, they are even more inert than the inert nitrogen of the air with which they are associated.

Argon was the first to be detected of these rare elementary gases. Its discovery was as follows: Rayleigh, a celebrated English chemist and physicist, while making an extended study of the density of some of the elementary gases, had prepared a quantity of nitrogen from the atmosphere in the condition known as *atmospheric nitrogen;* that is, nitrogen obtained from ordinary air by absorbing its oxygen by some readily oxidizable substance. Rayleigh found that a given quantity of this nitrogen weighed exactly 1.2571 grammes. Obtaining an equal volume of nitrogen by the decomposition of ammonia or nitric acid, he made the wonderful discovery that under exactly the same conditions of pressure and temperature, this latter variety of nitrogen was lighter than atmospheric nitrogen, weighing only 1.2507 grammes.

Now, it may seem to you that this is a very small difference; for, subtracting one number from the other we find that the atmospheric nitrogen was only .0064 grammes heavier than the other kind of nitrogen, a difference so small that one who is not a chemist or a physicist might regard it as unimportant. To Lord Rayleigh, however, it was a difference demanding careful investigation. As a result of this investigation, in which he was associated with William Ramsey, another celebrated English chemist, the wonderful discovery was made that the additional density of atmospheric nitrogen is due to the presence of a hitherto unsuspected elementary gaseous substance.

This newly discovered element was called *argon*, from a Greek word meaning idle or inactive. Argon is a colorless gas that has no odor whatever. Like all the ingredients of the atmosphere, when exposed to great pressure and cold, it is capable of being condensed to a colorless liquid.

Besides being present in the atmosphere, argon exists in certain meteorites, in a few rare minerals, and dissolved in the waters of certain mineral springs. The waters from certain boiling spings in Iceland contain more argon than air (namely, 1.14%).

Argon exists, not only in the atmosphere above the earth, but also in the crust of the earth from which it is removed by the subterranean waters, and in regions outside the earth, since we find it in meteorites.

One of the most satisfactory ways of distinguishing one element from another is by the use of a device known as the *spectroscope*. When an elementary gas or vapor is heated so as to emit light, and this light is passed through a prism, a number of colored rays are produced, that are different for each chemical element. In other words, no two elements produce exactly the same kind of colored rays. We can, therefore, easily distinguish one element from another by the peculiar colored rays it emits when sufficiently heated.

In order conveniently to obtain this light a device called a *Plücker tube* is used. This consists, as shown in Fig. 5, of a glass tube, c, c, the middle portion of which is provided with a fine bore of hair-like diameter, or, in other words, consists of a capillary tube. The ends of the capillary tube are connected with tubes of larger diameter, in the ends of which short pieces of platinum wire are fused as shown at P and N. The tube is then partially exhausted, and is then made air tight by the fusion of the glass at S, where it was connected with the air-pump during exhaustion.

The terminals of a *Ruhmkorff coil*, a device for readily obtaining electric sparks, are then connected to the termi-

FIG. 5. PLÜCKER TUBE

nals, at P and N. As the sparks pass through the nearly empty space within the tube, the few particles of air or gas remaining emit a brilliant light in the capillary portion of the tube, c, c. When the tube contains hydrogen only, the emitted light, when examined through a prism or a spectroscope, shows the presence of three separate colors, bright red, peacock blue, and violet; when containing nitrogen only, the light shows a number of hazy red, orange, yellow and yellow-green bands, besides a number of bands of a violet color. When the tube contains argon only, it shows in addition to the bands produced by nitrogen, certain groups of red and green lines that are not seen in the spectrum of any other known gas.

By permitting large quantities of liquefied air to boil away gradually, Ramsey discovered the gas *krypton* in the residue; for, liquid krypton volatilizes less rapidly than liquid air. The spectrum of krypton contains a bright red, a yellow, and a green line, the last of which is close to the line in the *northern light*, or the *aurora borealis*.

Another elementary gas, *xenon*, was found in the residue in liquid air along with krypton.

Two other elementary gases, helium and neon, were found in the most volatile part of liquefied air.

In order to form some idea of the very small quantities of these gases in the air I would say that Ramsey found that 600,000 litres[1] of air contained only four cubic centimetres of xenon.

At a somehat later date, March, 1895, Ramsey discovered that besides the above-mentioned gases, there was another element in the atmosphere called *helium*. This element had been previously detected by Lockyer in the sun's atmosphere. Helium is an inactive substance like argon. Associated with nitrogen, it exists in immense quantities in the photosphere or luminous atmosphere of the sun.

[1] One litre (one cubic decimetre) equals 61.0271 cubic inches; one cubic centimetre = .061027 cubic inch.

CHAPTER II

TORRICELLI AND HIS GREAT DISCOVERY

It all began with the Grand Duke of Tuscany. There can be no doubt about that. When the new pumps came they would not suck or draw water, and then there was trouble.

It is no wonder the Grand Duke was angry. He had set his heart on having those pumps in time to raise water for the fountains that were to play on his grounds during an approaching festival. He had instructed the pump-makers to construct for him the best pumps possible; and now, when they were tried, they would not work. The Grand Duke was angry. He was in the habit of having things go just his way, so when he found the pumps would not work he soundly berated the pump-makers.

It is true, when their royal customer had explained that the pumps were to be used to raise water fifty to sixty feet from the wells, the men told him that the greatest distance they had ever been able to get a pump to suck, or raise water, was about thirty-two feet. But this did not trouble the Grand Duke. He was ready to pay for the extra distance, and bade them go ahead and make better pumps. Willing to please the Grand Duke, and only too glad of the chance of making an extra charge, they made the pumps, and brought them to the Duke.

They were certainly good pumps; probably the best that had ever been made; but for all that, they were not able to raise the water from the deep wells.

Therefore, the Grand Duke was angry. He told the pump-makers that those pumps must be made to work, and made to work soon. Then there was great excitement.

Every one was suggesting things, both wise and otherwise, but nothing was of any use.

Now, when the Grand Duke found that the pumps could not be made to work, he said:

"Tell Galileo to come here."

This man's full name was Galileo Galilei. He was one of the most distinguished philosophers of Italy, and was born in Pisa, Italy, February 18th, 1564. When twenty-four years of age he was elected Professor of Mathematics at Pisa.

There is only space to tell a few of the remarkable things Galileo did for science.

It was Galileo who discovered that a pendulum takes the same time to make one complete swing to-and-fro, whether it is swinging through a wide path, or through a very small path. The pendulum Galileo used for this discovery was the great suspended lamp in the Cathedral, and having no watch, he employed the beating of his heart to tell the time. It was Galileo who built for himself an excellent telescope and with it made many wonderful discoveries in Astronomy. Among other things, he proved that the earth moved around the sun and not the sun around the earth; or, in other words, that the sun, and not the earth, was the centre of the solar system; and in this way he got himself into trouble.

His enemies were powerful and he was obliged to resign his professorship at Pisa. From this place he went to Padua, where he had such wonderful success as a teacher and lecturer that pupils came to him from all parts of Europe. He remained in Padua for eighteen years, when he was called back to Pisa and became the principal mathematician and philosopher of the Grand Duke.

It was natural, therefore, when no one was able to make the pumps work, that the Grand Duke should say: "Tell Galileo to come here." So Galileo came and the Grand Duke asked him to look at the pumps and get them to working properly. This trouble with the pumps occurred during the year 1641, and, as Galileo was born in 1564, he must at this time have been seventy-seven years of age. Old, blind, and shattered in health from the cruel treatment of his enemies it would not have been surprising if he had been unwilling to give his best thoughts to such work as this of the pumps. It appears, however, that he did the best he could for the Grand Duke, sending word that the trouble would be found in the valves; that if they were made better the pumps would work. The pumps were, therefore, sent back to the makers with instructions to make the valves work more freely. This was done, but still the water would not rise so Galileo was sent for again. Aided by his pupils, the philosopher once more tried to find out the difficulty, but, do what they would, they were unable to make the pumps suck or draw water to a greater height than thirty-two feet.

It seems difficult in our day, when the causes of natural phenomena have been so clearly traced by the hard labors of the many bright men who have lived before us, to understand fully just why there should have been any astonishment at a pump's failing to draw water for a greater distance than thirty-two feet. We know now that pumps practically operate on the principle of a balance, or pair of scales, the weight of the atmosphere on one side forcing a column of water up the pipe which dips down into the well until the weights of the column of air and the colum of water balance each other. Even if the pump had been so admirably made that it could produce a perfect vacuum in the pump barrel, or, in other words, even if it could suck all the air out of the well-pipe, the most that the pressure of the air, acting downwards on the water in the well, could do, would be to force up a column of water in the well-pipe until its height was such that the column of air and the column of water would exactly balance each other.

But neither the Grand Duke nor the pump-makers were to be blamed for their ignorance. At this time, 1641, it was not known that air possesses any weight, and thus it was not even suspected that the atmosphere exerts a downward pressure on the water in the well, or on other things on the surface of the earth.

You may ask how it was possible that intelligent people should have been using pumps for so long a time without finding out what made the water rise in the pump-pipe when the pump sucked all the air out of it. The reason was that, in those early days, men did not go about the study of natural phenomena in the proper way. Instead of actually trying experiments they attempted to reason out the causes of things, and up to that time the world had been satisfied with the following explanation: the water rises in the well-pipe connected with a pump, because, if it did not, there would be nothing left in the pipe, and "*nature abhors a vacuum.*" The world had been satisfied with this explanation up to 1641. And, indeed, this was the explanation that Galileo, great philosopher though he was, believed; for, when he found by actual trial that the pumps would not suck water through a greater height than thirty-two feet, he sent to the Grand Duke the following remarkable opinion. He said that the pumps would not operate because, although nature abhorred a vacuum, yet she did not abhor a vacuum greater than thirty-two feet of water; an opinion which, had it been delivered by the Delphic Oracle, could have been proved at this late day, when we know so much about atmosphere pressure, to have been true.

But, while Galileo was endeavoring to discover the cause of the pumps not sucking, or drawing water up in the pump-pipe higher than thirty-two feet, there was, among the many pupils who were trying to aid him, an especially bright young man named Evangelista Torricelli. As we have seen, no satisfactory solution of the difficulty was reached then; but Torricelli continued to give the problem so much thought that in 1643, less than a year after the death of his old master, he announced to the world his great discovery that water is raised in pump-pipes from wells by reason of the pressure of the air, and not by reason of any abhorrence of a vacuum. By this discovery Torricelli acquired a reputation in the scientific world that immortalized him.

It appears that the apparatus employed by Torricelli in his first experiment, was not, as is generally stated, the glass-mercury tube, but an apparatus made in imitation of the Grand Duke's pump. It consisted of a glass tube sixty feet long, placed in a perpendicular position, with its lower end below the surface of water. He applied a suction pump at the upper end of this tube and found that the best he could do was to raise the water thirty-two feet. He then reasoned to himself that, if the true cause of the water rising in the pump-pipe was, as he believed, the pressure of the air against the water in the well, if he employed a denser liquid such as mercury, the height to which the pressure of the air would raise it would be inversely proportional to its density.

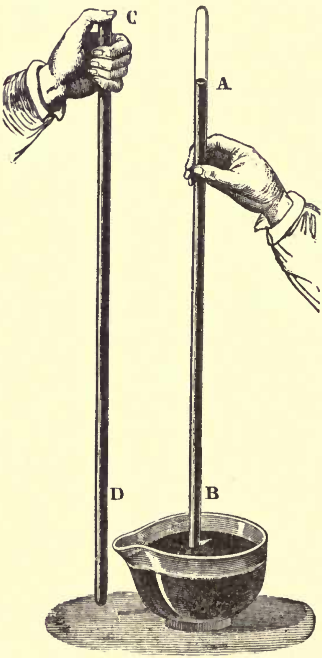


FIG. 6. TORRICELLI'S EXPERIMENT

Torricelli's experiment is now generally made as follows. The experimenter obtains a glass tube about four feet long, sealed at one end and open at the other, as shown in Fig. 6. Filling this tube with mercury and placing a finger over the open end, he inverts the tube and inserts the open end below the surface of a quantity of mercury in an open vessel. Then, holding the tube in a vertical position, he takes away his finger from the open end of the tube, when a part only of the mercury runs out, the rest being supported at a height of about thirty inches above the level of the mercury in the open vessel, as seen in Fig. 6. By this simple but beautiful method, it was practically in this way that Torricelli proved, beyond any reasonable doubt, that it is the pressure of the air and not the abhorrence of a vacuum that causes the water to rise from a well to a pump. Fig. 7 represents Torricelli in his laboratory, making his famous experiment. You can see from the picture that this experiment was made in his laboratory, for a few of the different kinds of apparatus he had used in other researches are also made. You can also see that here Torricelli is employing the mercury tube and not the water tube.

Fig. 7. Torricelli in His Laboratory

Torricelli's discovery caused great excitement when it became known in different parts of Europe. Of course, in those early days, no little time was required for news to spread. There was no telegraph or telephone, so that for the news to reach some countries a year or more was necessary.

I regret to say that in many parts of the world, when this great discovery was announced, intelligent men, instead of rejoicing that so great a secret of nature had at last been discovered, refused to accept Torricelli's explanation. They appeared to think that there was something wicked in rejecting the long cherished idea that nature abhors a vacuum.

The discovery of Torricelli was made in 1643. Unfortunately, Torricelli died shortly afterwards, in 1647. His experiments, however, were continued by other able philosophers. Among these was a distinguished French mathematician, Blaise Pascal.

Pascal was born in France in 1623. While a child he exhibited such proofs of ability in mathematics that he was kept in ignorance of geometry lest his fondness for it should interfere with his other studies. But one day his father was surprised at finding the lad (*then only twelve years old*) demonstrating on the pavement of an old hall in which he played, by means of a rude diagram traced with a piece of coal, a difficult theorem of Euclid, the great geometrician. Being permitted to continue his studies Pascal composed, when only sixteen years of age, a treatise on the conic sections, a very difficult branch of mathematics concerning circles, ellipses, hyperbolas, and parabolas, which aroused the admiration and astonishment of the greatest living mathematicians. When only nineteen years old he invented an arithmetical computing machine, and by the time he was twenty-six he had composed many mathematical works and made many experiments in pneumatics and hydraulics.

Pascal began experimenting with Torricelli's great discovery in 1646, one year before Torricelli's death. In repeating Torricelli's experiment, instead of employing mercury, Pascal used longer glass tubes closed at one end, which he filled with different kinds of liquids, such as wine or water, inverting these tubes in open vessels filled with the same kind of liquids.

Instead of meeting with approbation, Pascal's experiments were bitterly opposed. In order to demonstrate the correctness of Torricelli's discovery beyond any possibility of doubt, he planned the following experiment, which

I will let him describe in the following extract from a letter he sent to M. Perrier, his brother-in-law:

"I have thought of an experiment, which, if it can be executed with accuracy, will alone be sufficient to elucidate this subject. It is to repeat the Torricellian experiment several times in the same day, with the same tube, and the same mercury; sometimes at the foot, sometimes at the summit of a mountain 500 or 600 fathoms in height. By this means we shall ascertain whether the mercury in the tube will be at the same, or a different height at each of these stations. You perceive, without doubt, that this experiment is decisive; for, if the column of mercury be lower at the top of the hill than at the base, as I think it will be, it clearly shows that the pressure of the air is the sole cause of the suspension of the mercury in the tube, and not the horror of a vacuum; as it is evident there is a longer column of air at the bottom of the hill than at the top; but it would be absurd to suppose that nature abhors a vacuum more at the base than at the summit of a hill. For, if the suspension of the mercury in the tube is owing to the pressure of the air, it is plain it must be equal to a column of air, whose diameter is the same with that of the mercurial column, and whose height is equal to that of the atmosphere from the surface of the mercury in the basin. Now, the base remaining the same, it is evident the pressure will be in proportion to the height of the column, and that the higher the column of air is, the longer will be the column of mercury that will be sustained."

This great experiment was made on the 19th of September, 1648, on the highest mountain in France, the Puy de Dome, near Clermont. As Perrier climbed to the top of the mountain with the mercury tube, the mercury fell until it was three inches lower in the tube than it was at the base. The experiment was repeated on different sides of the mountain at different times up to the year 1651, and always with the same result.

Pascal made other similar experiments by carrying the mercury tube to the top of high steeples in Paris, and thus established, beyond any peradventure, the fact that the mysterious power which was known under the name of "nature's abhorrence of a vacuum," was really the pressure of the atmosphere.

Fig. 8.
Barometer

Torricelli's great discovery produced many important results. It was followed in 1664 by the invention of Otto Guericke, in Magdeburg, of the air-pump.

Another important result was the employment of Torricelli's mercury tube or, as it is now generally known, a *barometer*, for readily measuring the height of mountains or other elevations, as well as for a weather-glass, or instrument for determining coming changes in the weather. By means of a careful system of observations of the varying heights of the barometer at different points of the earth's surface, the United States Weather Bureau and other similar bureaus are capable of making fairly accurate prognostications of coming changes in the weather.

Various forms are given to the barometer. One of the simplest forms is shown in Fig. 6, page 22. Here a tube nearly four feet high is supported in a vertical position in a large reservoir filled with mercury. The height of the mercury column is measured from the upper surface of the mercury in the reservoir. In filling the barometer tube with mercury it is necessary to employ mercury that has been recently boiled, since, otherwise, the air the mercury contains would escape into the upper part of a tube and so injure the vacuum. When nearly full the tube is placed on a sloping furnace and heated until the mercury boils. In this way all moisture and air are driven out and a fairly high vacuum is obtained in the upper part of the tube, which is known as a Torricellian vacuum.

Fig. 8 shows the form generally given to the barometer. Here the barometer tube is placed inside a copper tube provided with two slits on opposite sides. The scale divisions are engraved on this tube, as is more distinctly shown on the right in Fig. 9. In the left the details of the reservoir are represented.

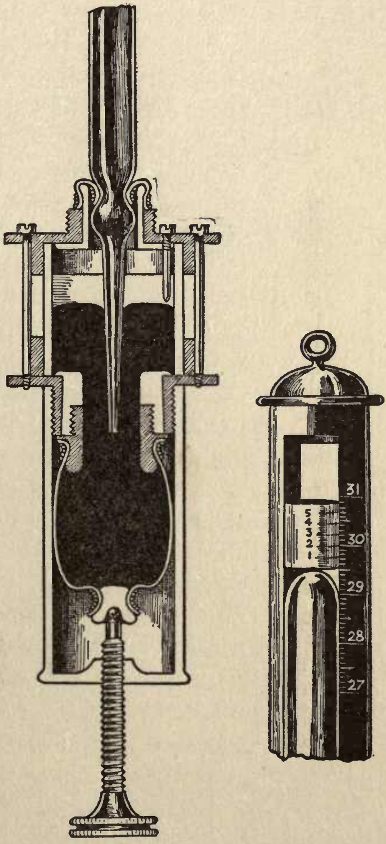


Fig. 9. Details of Barometer

Although we live at the bottom of the atmosphere, with the air pressing with enormous force against our bodies, yet it was not until Torricelli's discovery that the existence of this pressure was discovered. The reason is evident. The atmosphere is a very nearly perfect gas and, therefore, transmits pressure equally well in all directions; that is, upwards, downwards, sidewise, and obliquely. While it is true that the air exerts a considerable pressure against any part of the human body, as, for example, the back of the hand, yet it exerts an equal opposite pressure against the palm of the hand, these two pressures balancing each other. Moreover, an equal and outward pressure acting through the blood exists, so that we are unconscious of any pressure whatever. If, however, the pressure be removed from one side of the hand or any other part of the body, the opposite pressure will at once make itself felt in a very decided manner.

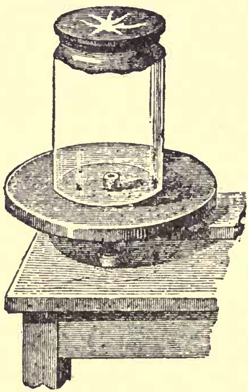


FIG. 10. BURST BLADDER

There are a number of simple experiments by means of which the pressure of the atmosphere can be shown. For example, if a glass cylinder, open at the bottom, and covered at the top with a tightly stretched piece of bladder be placed on the plate of an air-pump, as shown in Fig. 10, and a vacuum be created inside the cylinder by drawing out the air by means of an air-pump, as the pressure on the lower surface of the bladder is relieved the pressure on the upper surface manifests itself, so that, in a few moments, the bladder is burst with a loud report.

Otto Guericke contrived a piece of apparatus consisting of two hemispheres of metal as in Fig. 11, provided with well ground flat ends so made as to be accurately fitted together. These ends were smeared with lard and then placed one on top of the other, the lower hemisphere being connected with an air-pump. As the air is removed from inside the hemispheres, the pressure of the air on the outside forces or presses them together with such force that, unless the hemispheres are small, it is impossible to

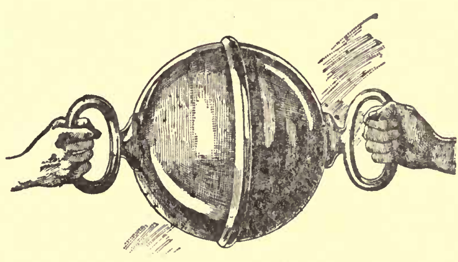


FIG. 11. MAGDEBURG HEMISPHERES

pull them apart until a stopcock is opened so as to permit the entrance of air. These hemispheres are named after the city in which Guericke lived, the *Magdeburg Hemispheres.*

It is said that the first piece of apparatus of this kind Guericke made and exhibited in public, was of such a size that when the air was exhausted from the inside, eight strong horses, four at each end, were unable to draw the hemispheres apart.

Since it is the pressure of the air that causes the mercury to rise in Torricelli's tube, it is not difficult to discover the exact value of the atmospheric pressure. Suppose, for example, we employ a tube the area of the opening of which is exactly one square inch, and that with such a tube, properly filled with mercury, the pressure of the air at a certain time and place is sufficient to cause the mercury to rise thirty inches in the tube. If, now, these thirty inches of mercury be weighed it will be found that they weigh approximately fifteen pounds. Therefore, the atmosphere at that particular part of the earth is pressing on every square inch of surface with a force of approximately fifteen pounds.

The atmospheric pressure is much greater than you might suppose; for it exerts on the body of a man of ordinary size a total pressure of more than fifteen tons. This pressure is not felt, however, because it is exerted equally in all directions, and the opposite pressures exactly balance each other.

The total weight of the atmosphere is equal to that of a huge globe of copper sixty-two miles in diameter; or, if it were possible to make a pair of balances large enough to hold all the atmosphere on one scale pan, about 138,000 cubes of solid copper, each one mile high, one mile wide, and one mile broad, would be required to balance it.

CHAPTER III

THE WONDERS OF ATMOSPHERIC PRESSURE

Many wonderful effects are produced by the pressure the air exerts, against objects immersed in it. It will therefore be interesting briefly to review some of these effects.

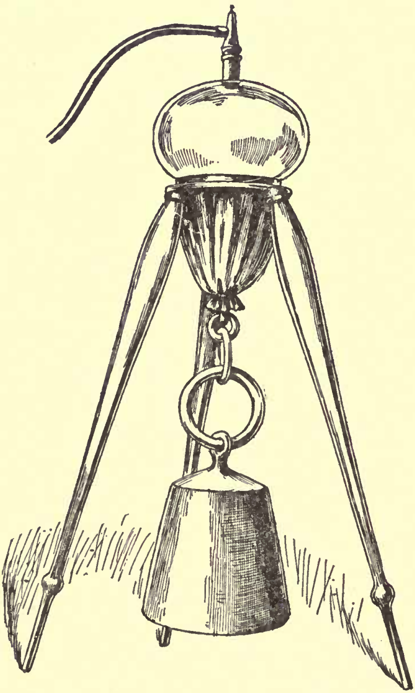


FIG. 12. WEIGHT MOVED UPWARD BY ATMOSPHERIC PRESSURE

There is a curious experiment shown by most lecturers on natural philosophy to prove how readily a heavy weight can be moved upwards into a cavity by the pressure of the air. The apparatus employed in this experiment assumes various forms, one of which is represented in Fig. 12. Here a globe provided with an open bottom, is supported on the tripod as shown. A stout rubber tube connects the globe with an air-pump. When the air is exhausted a yielding bag, which forms the movable bottom of the jar, is pressed upwards into the jar, even when carrying the heavy weight attached as shown.

There is something almost uncanny in seeing a heavy weight quietly picked up from the floor by some unseen force and sustained in midair, as on an elastic spring, by the pressure of the atmosphere.

You will probably be surprised to learn that the manner in which the weight is pushed by atmospheric pressure into the empty jar is exactly the same as that in which the food is shoved, or pushed down the throat of the huge snake, known as the anaconda or boa-constrictor.

The boa-constrictor is very different from most other animals in its habits of feeding. It only eats occasionally, but then it makes up for this by taking very large mouthfuls. It can swallow a deer or a goat whole. It does not chew its food by grinding it between its teeth, thus thoroughly mixing with saliva or spittle, and swallowing it in small pieces. It swallows its food whole. While most animals, when they can get food, eat several times every day, the boa-constrictor eats only once in three or four weeks.

The boa-constrictor envelops its prey in its folds and thus crushes it to death. It then swallows it whole, and becomes torpid, or goes to sleep until the meal is thoroughly digested.

Perhaps you remember a Thanksgiving Day, Christmas, or other time, when there was something at the table you especially liked and you ate a bigger meal than was wise; then you felt sleepy for a long time afterwards, until the food had been gradually dissolved in your stomach and partially absorbed into your system by a process called *digestion*. You will, therefore, understand how, after a boa-constrictor has swallowed whole a deer or a goat, it goes away and sleeps until the meal has been digested.

But we are especially interested here not in the size of the boa's meal, but in the manner in which it is swallowed. Having killed the animal, and thoroughly crushed its bones, it proceeds deliberately to cover the body with saliva. This is done, apparently, in order to obtain an air-tight joint between the body of the victim and the interior of the boa's throat. I think, however, that an additional advantage is gained by the saliva's aiding in the digestion of the animal.

The boa now takes the head of the animal in its mouth, and presses his jaws so close to it as to make an air-tight joint. It then alternately dilates and contracts its body so as to produce a partial vacuum within it, when the great pressure of the atmosphere, having a decreased resistance from the inside of the snake, acts on the body of the deer or goat, forces it into the flexible throat of the snake and soon has it lodged in its stomach. You can, of course, understand that, if the air should leak in at the sides of the mouth, it would not be possible to form a vacuum inside the snake's throat, so that the food would not be driven in by atmospheric pressure any more than the heavy weight, shown in the preceding figure, would be driven up into the cylinder were an opening cut anywhere in the tube that connects the cylinder with the air-pump.

Ewbanks, in his "Hydraulics," suggests that the manner of eating an unusually large raw oyster, at least in cases when the oyster is swallowed whole and digested in the eater's stomach, is not unlike the method adopted by the anaconda, except that the oyster needs no licking to render it slippery; for the man desiring to swallow the oyster approaches his lips to the oyster as it lies on one of its shells, and holds them close to its body, so as to make an air-tight joint. He then dilates his chest by the act of drawing in air. The air now attempting to rush into his mouth drives the oyster before it with a somewhat astonishing velocity.

You may be surprised to learn that a method similar to that employed by the boa-constrictor or the oyster-swallower for transferring food to the stomach, is sometimes employed for firing projectiles from guns.

This strange kind of gun was originally invented by Guericke and Papin for projecting bullets by rarefied air. In it the bullets are fitted into the breech in the gun-barrel, the end of which is temporarily closed, and a vacuum is produced in front of the ball; then the pressure of the air is suddenly permitted to come on the back of the ball which is driven through the gun-barrel with a velocity of, perhaps, 1,000 feet per second. Now, this is what occurred to the saliva-covered deer, or the slippery oyster; for, a vacuum being formed on the side of the food towards the stomach, on the attempt to take in a breath the dilation of the person's chest, or the contortion of the snake's body, permits the atmospheric pressure to propel the deer or oyster into the stomach, though, of course, with far less dangerous velocity.

Were it not that the pressure of the blood exerted inside the body tends to press the flesh and skin outward, the enormous pressure the atmosphere exerts would crush our bodies with as great certainty as if a heavily loaded wagon should be driven over them. These opposite pressures—the pressure of the blood outward and the atmospheric pressure inward—balance each other. If, however, the atmospheric pressure is removed from one part of the skin and a cut or abrasion is made in the skin, the pressure of the heart would drive the blood rapidly out through the opening.

The practice of blood-letting, at one time quite common, consisted in withdrawing a considerable amount of blood from the body. The blood was withdrawn by opening one of the veins, generally in the arm, and letting sufficient blood run out, when the bleeding was stopped by a bandage. This was called general blood-letting, because the blood was thus withdrawn from all parts of the body. In local blood-letting, however, when the blood was to be taken from some particular part of the body, a blood-sucking leech was attached to this part and permitted to suck the blood of the patient, until, becoming gorged, it could be readily removed. Or local blood-letting was accomplished by what is called *cupping.*

In cupping, a device called a *cupping-glass* was employed. This consisted of a cup-shaped vessel, the air in which was heated by holding it over a spirit-lamp. It was then suddenly placed over the part which was to be cupped, which part had first been slightly cut in numerous places by sharp lancets. The heat of the spirit-lamp when the cupping-glass was held over it rarefied the air and thus made a partial vacuum, so that when the glass was applied to the portion of the skin to be cupped the air pressure upon the skin was so reduced that the blood readily escaped and filled the cup. Sometimes a small air-pump was attached to the cupping-glass thus permitting a vacuum to be formed without the use of heat, and this is the method now practiced.

A very simple piece of apparatus intended for use in connection with an air-pump, known as the *hand-glass*, consists, as shown in Fig. 13, of a glass open at both top and bottom. The top, however, is much smaller than the bottom, so that it may be readily covered by the palm of the hand. The bottom is ground smooth so as to make an air-tight joint when placed on the plate of the air-pump. Now, while the hand-glass is on the pump-plate, if a person places his hand so as completely to cover the upper end of the glass, and the air is exhausted from within the glass, it will be impossible for the person to remove his hand; for the pressure of the air upon it will almost equal the weight of a barrel of flour.

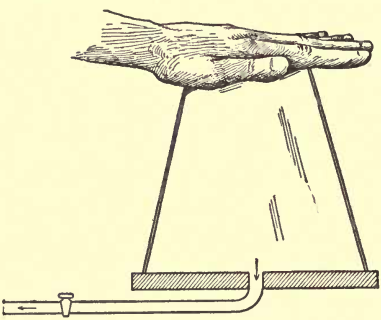


Fig. 13. Hand-Glass

It greatly surprises the person whose hand has been placed on the top of the glass to find it suddenly pressed and held with so great a force. One can readily understand, therefore, the great surprise and horror of the chief of a delegation of Pottawattamie Indians to the United States seat of government at Washington, when, in order to show them some of the magic of the white man, the chief was asked to place his hand on the top of a hand-glass, and was told that their magic would be able to powwow the hand, so as to prevent him from lifting it. With a contemptuous smile for the white men who could believe such nonsense, the Indian confidently placed his hand on the hand-glass; but, when the vacuum was created, he found to his horror that he was unable to free himself. At last, losing his accustomed stoicism, he cried out in terror for his companions to help him, which, indeed, they were ready to do, flourishing their tomahawks and rushing towards the white man who was thus wickedly casting this spell upon their chief. And it was with great difficulty that they were dissuaded from wreaking a summary vengeance.

Another experiment can also be tried without an air-pump by the use of a tumbler provided with a smooth upper rim. Fill the tumbler nearly to the brim with water and place a piece of stout paper over the top. Holding the glass with one hand, place the palm of the other over the paper so as to hold it in position, and quickly invert the tumbler and remove the hand that holds the paper. The pressure of the air acting upwards against the paper, being greater than the weight of the water in the tumbler, will prevent the water from running out.

It is very curious to see the water kept in the tumbler by the invisible atmospheric pressure which holds the sheet of paper firmly in place. If, however, while the paper is still being pressed upwards, you permit air to enter, by pulling down one corner, the water will suddenly escape from the tumbler.

But you need not pull the paper partially away to let the air into the tumbler. If an opening be made in any part of the tumbler, so long as this opening is covered by a finger so as to prevent the entrance of air, the water will remain in the tumbler; but as soon as the finger is removed the air enters, the paper falls off and the water escapes.

A very curious modification of this experiment can be made by employing, in place of the tumbler, a form of glass vessel known as a *beaker,* used in the laboratory for heating liquids. This vessel is shaped somewhat like a tumbler only it is provided with a curved edge at its top. Now, if such a vessel is taken and the top covered by a piece of mosquito netting or gauze stretched tightly over it and held in place by means of a string, the gauze will permit the vessel to be readily filled with water by pouring it through the meshes.

If a piece of paper be placed over the mosquito netting after the beaker is filled with water, and this paper be held in position as before and the beaker inverted, the paper may be withdrawn or slipped from under the beaker without the water's running out. This is certainly a very astonishing experiment, and may properly be regarded as one of the wonders of atmospheric pressure. Like all wonders, however, as soon as it is explained, it becomes only an ordinary matter-of-course fact; for the little particles of which water are formed so cohere, or cling together, that they can be regarded as corks that serve to stop or plug up the separate holes in the mosquito netting.

You may not at first succeed with this experiment, since it is necessary to hold the beaker steadily so that the mosquito netting shall be kept in an exactly horizontal position. You must keep your hand from trembling, for a slight jolt given to the vessel may dislodge the water corks and let in the air. Moreover, it is necessary not only that the particles of water of which these water corks consist shall cohere or cling together, but also that they shall adhere, or stick to the sides of the mosquito netting forming the holes, and this requires that the mosquito netting be quite clean and free from grease.

A simple modification of the above experiment will be found much easier to try. Take an old sugar-duster or flour dredger, which, as you know, consists of a metal box the top of which is perforated with a great number of small holes. Make a hole in the bottom of the box with a nail, see that both the inside and outside are clean or free from grease, and immerse it, bottom up, below the surface in a bucket of water. The water will run in at the bottom, and the air will run out at the top. As soon as the box is filled, take hold of it by the handle; place a finger over the hole in the bottom, and lift it from the water. None of the water will run out. Momentarily raise the finger from the hole at the top, and streams of water will instantly escape from all the small orifices in what is now the bottom. But, strange to say, the flow will instantly cease as soon as the finger is placed over the little opening you made with the nail.

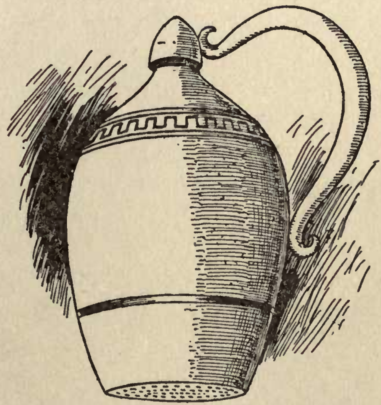


FIG. 14. ATMOSPHERIC WATERING POT

Apparatus of this character have been employed from very early times, and were known as *atmospheric sprinkling pots* or watering pots. Athenagoras, who lived in the fifth century B. C., describes the instrument as follows:

"This instrument, which is acuminated [pointed] at the top and made of clay or other materials (and used as it often has been for the watering of gardens) is, in the bottom, very large and plain [flat], but full of small holes like a sieve. But at the top it has only one large hole."

The general appearance of the atmospheric watering or sprinkling pot is shown in Fig. 14.

It was filled by plunging it below the surface of water, which entered by the numerous holes in the bottom, the air being driven out through the single large hole at the top, as in the experiment with the dredge-box. When it was lifted from the water the hole in the top was closed to keep out the air, the finger being removed from the opening whenever it was desired to let the water run out; and the escape of the water could readily be stopped again by replacing the finger over the hole.

Fig. 15. Watering Pot as Used by the Greeks

Another representation of a sprinkling or gardening pot of the Greeks is represented in Fig. 15.

Before closing this chapter, I will tell you how Tutia, one of the vestal virgins, saved her life by what was called a miracle but was, in reality, only an ingenious application of the old sprinkling pot.

The goddess Vesta was supposed to preside over the sacred fire burning in the temple or on the household hearths. The hearth of the home was regarded as sacred because it was the shrine of Vesta, and, therefore, the family altar. The Greeks and Romans, in common with nearly all the ancients, regarded fire as sacred, and always kept it burning in their temples. Each large city had its own particular fire, which was considered so sacred that, when colonists were sent to different parts of the world, they always carried with them some of the sacred fire from the common hearth. Should this fire be accidentally extinguished, it had to be rekindled by the holy fire from the sun, concentrated by a brightly polished concave mirror of brass.

It was the duty of the vestal virgins to tend the sacred fire. They were, therefore, chosen for this important work on account of the pure and strict life they led. They were held in very high repute among the people and enjoyed many privileges and much honor. But should they permit the holy fire to go out it was thought that some great national calamity would happen; and if any one of them broke the vows of chastity she was doomed to be buried alive.

Now, a charge was brought against Tutia that she had broken her vow and should therefore suffer this dreadful punishment. Tutia passionately declared her innocence and called on the goddess Vesta to perform a miracle, so as to prove her innocence.

"Enable me," she prayed, "to carry a sieve full of water from the Tiber to thy temple without spilling a drop."

Of course, the people were bound to leave the proof of her innocence to the goddess whose temple it was claimed she had profaned. Indeed, they were glad of an opportunity for the holiday they would make out of this extraordinary occasion. The test was made and Tutia succeeded in carrying a sieve full of water to the temple from the Tiber without spilling a drop, and thus proved her innocence.

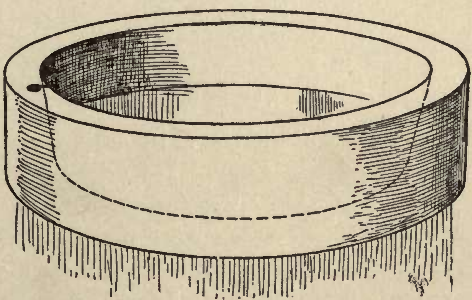


Fig. 16. Double Sieve

Of course, the so-called miracle was dependent on natural principles that were thoroughly familiar to Tutia's friends. While it cannot be certainly said how the thing was done, yet it is quite probable, as Ewbanks suggests, that the sieve was constructed on a modification of the form of the old sprinkling pot. It was probably a double sieve, as shown in Fig. 16, the bottom and sides of which were hollow, the exterior bottom being perforated. The upper edges were united and made air-tight, with the exception of a hole near the edge that was closed by the fingers, while the sieve was being carried. Of course, such a sieve when slowly pressed below the surface of water in the river would permit the liquid to enter through the perforations, the contained air being driven out of the openings at the top. Then, by covering these openings with the fingers, the sieve would be raised from the river and safely carried by Tutia to the temple without any water escaping. As soon as the altar was reached, by sliding the fingers to one side the air would enter and the water escape, to the astonishment of the spectators, who were too far off to see the peculiar construction of the sieve. If, afterwards, the accusers demanded the right of examining the sieve, the real sieve could be hidden as soon as the trial was completed, and another sieve resembling the one employed be ready for examination whenever the demand was made.

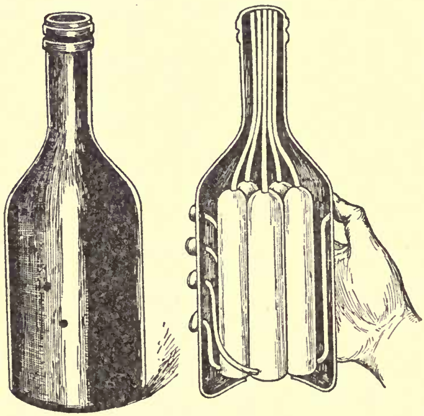


FIG. 17. THE MAGIC BOTTLE

It is an interesting fact that, in these later years, an apparatus dependent on this principle and known as the *magic bottle* is frequently employed by conjurors. This bottle consists, as shown in Fig. 17, of a bottle of sheet iron inside which are five separate bottles arranged as shown in cross section on the right hand side of the figure. These bottles are filled with different liquids by means of a small funnel.

Their openings in the mouth of the large bottle are left uncovered. The openings, however, at the bottom communicate with openings on the sides of the large bottle by means of small tubes as shown. These openings can be closed by the four fingers and the thumb of one hand.

When kept closed by the fingers, the bottle can be inverted without any of the liquids escaping, a fact which the exhibiter declares proves that there is nothing in the bottle. He asks any one in the audience to call for some particular kind of drink, say sherry, champagne, soda water, or milk and then raising the finger or thumb from the opening to the bottle containing a colored liquid most nearly resembling the liquid called for, he lets the liquid escape from the particular vial containing that liquid.

CHAPTER IV

SUCKERS

You will probably be surprised by this curious chapter heading, but I have given the chapter this title because it so clearly describes a large class of Wonders of the Atmosphere that are caused by atmospheric pressure.

The sucker especially referred to in the chapter heading is a scientific plaything that, when I was a boy, was well

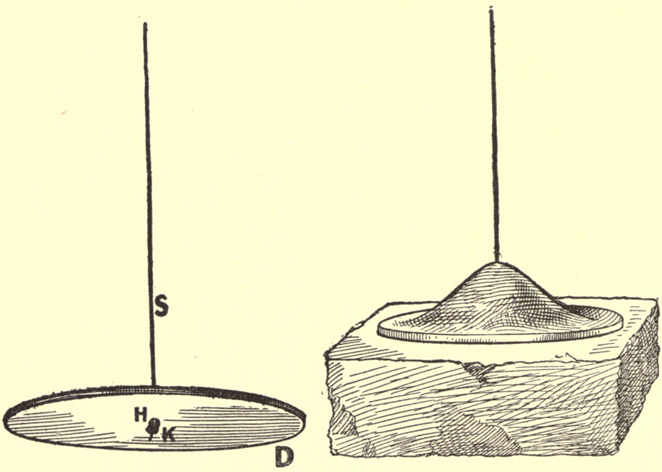


FIG. 18. SUCKERS

known to most boys; and it may still, for aught I know, be a common plaything, although I do not remember seeing it often lately. It is made as follows: a disc, or round piece, D, Fig. 18, of good soft leather is soaked in water until it becomes pliant and soft. In the centre of the disc a small hole H, is pierced through which a strong string S, knotted at one end K, is passed. This string must be of such a size as to fit the hole in the leather disc so tightly as to be air-tight.

If now, while the string is held tight, the side containing the knot be placed on the upper surface of a smooth brick which has been wetted so as to ensure an air-tight joint, and pressed against the surface with the foot, so as to drive out all the air, the pressure of the atmosphere acting against the top will hold it so firmly against the brick that the brick may be raised by the pulling of the string attached to the sucker. Indeed, even a flat-topped stone much heavier than a brick can be raised in the same manner.

You must not suppose that the sucker is an unusual thing. On the contrary, the principle of the sucker is employed in nature in various operations that are continually going on all around us. Suppose we examine some of them; for I am sure they will not only greatly interest you, but will, in many cases, prove a source of wonderment.

To begin with a common instance, you have doubtless watched a fly walking or running rapidly over the smooth ceiling of a room; or up or down a vertical sheet of glass in a window; or walking, head downwards, on the under side of a plate of glass in the case in which a confectioner keeps his bonbons. You have probably often wondered how the fly can keep from falling as he thus walks upside down. It certainly cannot be by having any sticky substance on his feet. Of course it would be very easy to obtain the material which would cause a fly's feet to stick to a ceiling or other surface, as, indeed, some of these poor animals have discovered to their cost, when they happened to tread on a sheet of fresh flypaper. But it would be impossible for them to cling at one moment to the wall or sheet of glass, and at the next moment free themselves from it; for, as you know, a fly can run over the surface of a ceiling too rapidly for you to watch the successive movements of its feet.

The wonder of the fly's ability to walk upside down at once disappears when you learn that the feet of the fly, tiny as they are, are provided by nature with devices closely resembling the ordinary leather sucker of the boy. When a fly wishes to cling upside down to a smooth ceiling, it spreads out the soles of its feet and makes them touch the ceiling in such a manner as to exclude the air beneath them, and, when the weight of the body tends to pull the fly away, it is kept firmly in position by the pressure of the atmosphere. It is evident, too, that the fly can quickly raise the edges of the sucker-like discs on his feet and thus spoil the vacuum by permitting the air to flow underneath; for he is able to run rapidly over the ceiling, head downwards.

But flies are by no means the only animals that are capable of walking in this position. In his History of Sumatra, published in London, 1811, page 119, Mr. Marsden asserts that he has seen lizards four inches in length walking over the ceiling of a room; and one ran with sufficient speed to overtake a cockroach, which it caught and eagerly devoured.

A variety of lizard, of India and other tropical countries, called the gecko, is provided with sucker-like attachments to its feet, by means of which it can run up the smoothest polished walls, even while carrying a load equal to its own weight.

Jesse, in a book called "Gleanings of Natural History," asserts that the common frog possesses suckers on its toes by means of which it is capable of climbing smooth walls. The account he gives of this is as follows:

"I may here mention a curious observation I made in regard to some frogs that had fallen down a small area which gave light to one of the windows of my house. The top of the area, being on a level with the ground, was covered over with some iron bars through which the frogs fell. During dry and warm weather when they could not absorb much moisture, I observed them to appear almost torpid; but when it rained they became impatient of their confinement and endeavored to make their escape, which they did in the following manner. The wall of the area was about five feet in height and plastered and white-washed as smooth as the ceiling of a room; upon this surface the frogs soon found that their claws would render them little or no assistance; they therefore contracted their large feet so as to make a hollow in the centre, and by means of the moisture which they had imbibed in consequence of the rain, they contrived to produce a vacuum, so that by the pressure of the air on their extended feet (in the same way that we see boys take up a stone by means of a piece of wet leather fastened to a string) they ascended the wall and made their escape. This happened constantly (frequently) in the course of three years."

The tree frog possesses a similar power of climbing but in a much more remarkable manner.

There are so many instances of animals that are provided with sucker-like discs on their feet, or on various parts of their bodies, which enable them to cling with considerable force to the smooth surfaces with which they come in contact, that I hardly know which to describe to you. Such attachments are quite common among certain kinds of fish. Perhaps one of the most remarkable is the *remora*, or *sucking fish*, common in the Mediterranean Sea. This fish is provided with a sucker-like disc, by means of which it is able to attach itself so firmly to a flat surface, that the only way in which it can be dislodged is by slipping it along.

These sucking fish are very poor swimmers, so that in order to move rapidly through the water and thus procure their food, they attach themselves to the bottom or sides of moving vessels, or to other fish. This particular species, however, is not to be regarded as a parasite, since it does not attach itself to the fish in order to live on its flesh. Dampier, a traveller, thus describes a specimen of the remora:

"From the head to the middle of its back there groweth a sort of flesh of a hard gristly substance, like that of the limpet. This excrescence is of a flat oval form, about seven or eight inches long, and five or six broad, and rising about half an inch high. It is full of small ridges with which it will fasten itself to anything that it meets with in the sea. When it is fair weather and but little wind, they will play about a ship, but in blustering weather, or when the ship sails quick, they commonly fasten themselves to the ship's bottom, from whence neither the ship's motion, though never so swift, nor the most tempestuous sea can remove them. They will likewise fasten themselves to any bigger fish, for they never swim fast themselves, if they meet with anything to carry them. I have found them sticking to a shark after it was hauled in on deck, though a shark is so strong and boisterous a fish, and throws about him so vehemently when caught, and for half an hour together, that did not the sucking fish stick at no ordinary rate, it must needs be cast off by so much violence."

Perhaps one of the most curious facts connected with sucking fish like the remora is the enormous force with which it attaches itself to the body of an animal. When Columbus was on the coast of San Domingo, he was surprised by the novel method of fishing employed by the people on that island; for they employed these fish as a species of animated fishing line and hook for the catching of other fish. We are told in Irving's "Columbus" that the method thus employed is as follows:

"They had a small fish, the flat head of which was furnished with numerous suckers, by which it attached itself so firmly to any object as to be torn in pieces rather than abandon its hold. Tying a long string to the tail, the Indians permitted it to swim at large; it generally kept near the surface till it perceived its prey, when, darting down swiftly, it attached itself to the throat of a fish, or to the under shell of a tortoise, when both were drawn up by the fisherman."

A similar mode of fishing is employed on the eastern coast of Africa near Zanguebar, where the natives employ a live remora, or sucking fish, in catching turtles. A couple of strings are fastened to the fish, one at the head and the other at the tail, and the fish is let down into the water among the halfgrown or young animals. When the fish fastens itself to a turtle, as it soon does, the fish and the turtle are drawn up together out of the water.

Very remarkable stories have been told by the ancients concerning the power of the remora to stop a vessel when under sail by attaching itself to the rudder. These stories must be taken with some allowance for as is well-known there is a marked tendency in many travellers to draw largely on their imagination.

The *lamprey*, an eel-like form of fish, possesses the power of attaching itself to rocks or boats, or to other fish, by means of sucker-like attachments on its mouth.

These fish are generally provided with a number of sucking discs in the mouth. The lampreys, however, differ from the remora; they are true parasites. They attach themselves to other fish by means of their sucker-like mouths, not for the purpose of being carried through the waters, but so as to live on the fish to which they have affixed themselves. Considerable damage is done to the food-fish of the world by this form of parasite. The United States Fish Commission have made a careful study of the lamprey for the purpose of discovering the best method of destroying this enemy of the food-fish they are endeavoring to propagate.

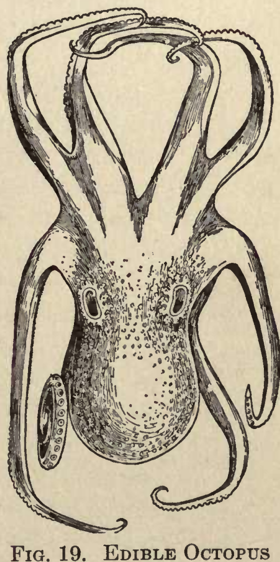


Fig. 19. Edible Octopus

In the common *blood-sucking leech,* you have an opportunity of examining an animal that possesses, to a marked degree, the power of hanging on to another animal by means of a sucker-like disc which is attached to its mouth; for if when you were in bathing you have ever had one of these animals attach itself to your body, you know by experience the force with which it can hold on, and how difficult it has been to remove it until it has become gorged with the blood that it has sucked from you.

Another excellent example of an animal provided with sucker-like attachments is to be seen in the fish known as the *devil-fish.* One species of this animal, known as the oc-

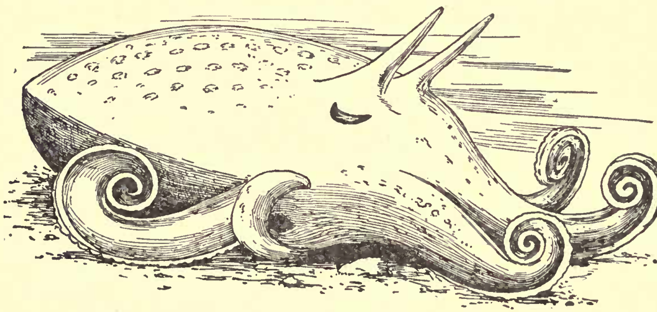


Fig. 20. Octopus

topus, is found on rocky shores in the warm waters of the world, especially in parts of the Mediterranean Sea. They have long arms of unequal length, each of which is provided with double rows of suckers, and with these they seize their prey. Fig. 19 shows a variety of octopus known as the edible octopus which is highly esteemed as an article of food in some of the countries bordering on the Mediterranean Sea.

Another variety of octopus is represented in Fig. 20.

Another variety of fish provided with sucker-like discs on its arms is known as the *cuttle-fish.* The general appearance of this is shown in Fig. 21.

It is from a variety of cuttle-fish known as the *sepia,* sometimes called the inkfish, that the dark pigment employed by the Chinese in the manufacture of *India ink* is obtained. This ink-like material is secreted in a bladder beneath the throat of the animal. When the fish is pursued by some of its enemies it emits this fluid and, concealing itself in the waters which it has thus darkened, easily escapes. The cuttle-fish possesses an internal shell corresponding to the material you have seen in the cages of canary-birds. Many years ago its bone was highly esteemed by apothecaries and others as an absorbent.

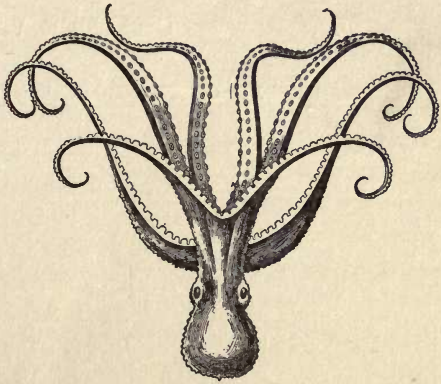


Fig. 21. Cuttle-Fish

I might describe a number of other animals that have sucker-like appendages, but these, I think, will be sufficient.

There are notable instances in the vegetable kingdom of sucker-like appendages by means of which climbing plants cling to sides of trees, or to the walls of buildings. If you will examine the variety of *ivy* that attaches itself to the walls of churches and other buildings, you will see the little discs by means of which the plant holds on to the surfaces with which it comes in contact. The force with which they hold on is so great that in any attempt to separate them, the portions of the plants to which they are attached are usually torn asunder.

CHAPTER V

THE GENIE OF THE BOTTLE—COMPRESSED AIR

The following story of the genie of the bottle as told by the fisherman in the Arabian Nights' Entertainment, will, I am sure, interest you; I wish you to read it carefully, since I hope to be able to use it to make somewhat easier a number of difficult phenomena or wonders of the atmosphere.

"There was formerly an aged fisherman, who was so poor that he could barely obtain food for himself, his wife, and three children, of which his family consisted. He went out early every morning to his employment; and he had imposed a rule upon himself never to cast his nets above four times a day.

"One morning he set out before the moon had disappeared: when he had got to the seashore, he undressed himself, and threw his nets. In drawing them to land, he perceived a considerable resistance, and began to imagine he should have an excellent haul, at which he was much pleased. But the moment after, finding that, instead of fish, he had got nothing but the carcass of an ass in his nets, he was much vexed and afflicted at having had so bad a draught. When he had mended his nets, which the weight of the ass had torn in many places, he threw them a second time. He again found considerable resistance in drawing them up, and again he thought they were filled with fish; how great, then, was his disappointment in discovering only a large pannier or basket, filled with sand and mud.

"He threw them a third time, and brought up only stones, shells, and filth. It is impossible to describe his despair, which almost deprived him of his senses. The day now began to break, and, like a good Mussulman, he did not neglect his prayers. When he had finished, he threw his nets for the fourth time. Again he supposed he had caught a great quantity of fish, as he drew them with as much difficulty as before. He nevertheless found none, but discovered a vase or bottle of yellow copper, which seemed, from its weight, to be filled with something, and he observed that it was shut up and fastened with lead, on which there was the impression of a seal. 'I will sell this to a founder,' said he, with joy, 'and with the money I shall get for it I will purchase a measure of corn.'

"He examined the vase on all sides; he shook it, in order to discover whether its contents would rattle. He could hear nothing; and this, together with the impression of the seal on the lead, made him think it was filled with something valuable. In order to find this out, he took his knife, and got it open without much difficulty. He directly turned the top downwards, and was much surprised to find nothing come out; he then set it down before him, and while he was attentively observing it, there issued from it so thick a smoke that he was obliged to step back a few paces. This smoke, by degrees, rose almost to the clouds, and spread itself over both the water and the shore, appearing like a thick fog. The fisherman, as may easily be imagined, was a good deal surprised at this sight. When the smoke had all come out from the vase, it again collected itself, and became a solid body, and then took the shape of a Genius, twice as large as any of the giants. At the appearance of so enormous a monster, the fisherman wished to run away, but his fears were so great he was unable to move.

"'Solomon, Solomon,' cried the Genius, 'great prophet, pardon, I pray. I never more will oppose thy will, but will obey all thy commands.'

"The fisherman had no sooner heard these words spoken by the Genius than he regained his courage, and said, 'Proud spirit, what is this thou sayest? Solomon has been dead more than 1800 years.—Inform me, I pray, of thine history, and on what account thou wast shut up in this vase.'

"To this speech the Genius, looking disdainfully at the fisherman, answered, 'Thou art very bold to call me a proud spirit; speak to me more civilly, before I kill thee.' 'And for what reason, pray, will you kill me?' answered the fisherman; 'have you already forgotten that I have set you at liberty?' 'I remember it very well,' returned he, 'but that shall not prevent my destroying thee, and I will only grant you one favour.' 'And pray, what is that?' said the fisherman. 'It is,' replied the Genius, 'to permit thee to choose the manner of thy death.' 'But in what,' added the other, 'have I offended thee? Is it thus thou wouldst recompense me for the good I have done thee?' 'I can treat thee no otherwise,' said the Genius; 'and to convince thee of it, attend to my history.

"'I am one of those spirits who rebelled against the sovereignty of God. All the other Genii acknowledged the great Solomon, the prophet of God, and submitted to him. Sacar and myself were the only ones who were above humbling ourselves. In order to revenge himself, this powerful monarch charged Assaf, the son of Barakhia, his first minister, to come and seize me. This was done; and Assaf took and brought me, in spite of myself, before the throne of the king, his master.

"'Solomon, the son of David, commanded me to quit my mode of life, acknowledge his authority, and submit to his laws. I haughtily refused to obey him, and rather exposed myself to his resentment than take the oath of fidelity and submission which he required of me. In order, therefore, to punish me, he enclosed me in this copper vase; and, to prevent my forcing my way out, he put upon the leaden cover the impression of his seal, on which the great name of God is engraven. This done, he gave the vase to one of those Genii who obeyed him, and ordered him to cast me into the sea; which, to my great sorrow, was performed directly.

" 'During the first period of my captivity, I swore that if any one delivered me before the first 100 years were passed, I would make him rich. The time elapsed and no one assisted me: during the second century, I swore that if any released me, I would discover to him all the treasures of the earth, still I was not more fortunate. During the third, I promised to make my deliverer a most powerful monarch, to be always hovering near him, and to grant him every day any three requests he chose. This age, too, like the former, passed away, and I remained in the same situation. Enraged at last, to be so long a prisoner, I swore that I would, without mercy, kill whoever should in future release me, and that the only favour I would grant him should be, to choose what manner of death he pleased. Since, therefore, thou hast come here to-day, and hast delivered me, fix upon whatever kind of death thou wilt.'

" The fisherman was much afflicted at this speech. 'How unfortunate,' he exclaimed, 'am I, to come here and render so great a service to such an ungrateful object? Consider, I entreat you, your injustice, and revoke so unreasonable an oath.' 'No,' answered the Genius, 'thy death is certain; determine only how I shall kill thee.' The fisherman was in great distress at finding him thus resolved on his death. He still endeavored to appease the Genius. 'Alas!' he cried, 'have pity on me, in consideration of what I have done for thee.' 'I have already told thee,' replied the Genius, 'that it is for that very reason that I am obliged to take thy life. Let us lose no time, your arguments will not alter my resolution. Make haste and tell me how you wish to die.'

" Necessity is the spur to invention; and the fisherman thought of a stratagem. 'Since, then,' said he, 'I cannot escape death, I submit to the will of God; but before I choose the sort of death, I conjure you, by the great name of God, which is graven upon the seal of the prophet Solomon, the son of David, answer me truly to a question I am going to put to you.' The Genius trembled at this adjuration, and felt that he should be compelled to answer positively. He then said to the fisherman, 'Ask what thou wilt, and make haste.'

"The Genius had no sooner promised to speak the truth than the fisherman said to him, 'I wish to know whether you really were in that vase; dare you swear it by the great name of God?' 'Yes,' answered the Genius, 'I swear it by the great name of God that I most certainly was.' 'In truth,' replied the fisherman, 'I cannot believe you. This vase cannot contain one of your feet; how then can it hold your whole body?' 'I swear to thee, notwithstanding,' replied he, 'that I was there just as thou seest me. Wilt thou not believe me after the solemn oath I have taken?' 'No, truly,' added the fisherman, 'I shall not believe you unless I were to see it.'

"Immediately the form of the Genius began to change into smoke and extended itself, as before, over both the shore and the sea; and then, collecting itself, began to enter the vase, and continued to do so, in a slow and equal manner, till nothing remained without. A voice immediately issued forth, saying, 'Now, then, thou incredulous fisherman, dost thou believe me now I am in the vase?' But instead of answering the Genius, he immediately took the leaden cover, and put it on the vase. 'Genius,' he cried, 'it is now your turn to ask pardon, and choose what sort of death is most agreeable to you. But no; it is better that I should throw you again into the sea, and I will build, on the very spot where you are cast, a house upon the shore, in which I will live, to warn all fisherman that shall come and throw their nets, not to fish up so wicked a Genius as thou art, who makest an oath to kill the man who shall set thee at liberty.'

"At this offensive speech, the enraged Genius tried every method to get out of the vase, but in vain; for the impression of the seal of Solomon, the prophet, son of David, prevented him. Knowing then that the fisherman had the advantage over him, he began to conceal his rage. 'Take care,' said he, in a softened voice, 'what you are about, fisherman. Whatever I did was merely in joke, and you ought not to take it seriously.' 'O Genius,' answered the fisherman, 'you who were a moment ago the greatest of all the Genii, are now the most insignificant; and do not suppose that your flattering speeches will be of any service to you. You shall assuredly return to the sea; and if you passed all the time there which you have stated, you may as well remain till the day of judgment. I entreated you, in the name of God, not to take my life, and you rejected my prayers, I now reject yours, likewise.'

"The Genius tried every argument to move the fisherman's pity, but in vain. 'I conjure you to open the vase,' said he, 'if you give me my liberty again, you shall have reason to be satisfied with my gratitude.' 'You are too treacherous for me to trust you,' returned the fisherman; 'I should deserve to lose my life if I had the imprudence to put it in your power a second time.'"

You, of course, look on this story as ridiculous although interesting. You probably say, "I will never believe it posible to get so great a quantity of matter inside a small copper bottle. Why this would beat the crowding or squeezing of a great number of things that I know can sometimes be placed in a well packed trunk."

Now while I by no means ask you to believe the story of the bottled genie, yet I can assure you that the story is by no means as improbable as it at first sight appears. It *is* possible to crowd a great quantity of certain substances in exceedingly small spaces, and this is especially true of the nitrogen, oxygen, and other gases that form our atmosphere. If this crowding be done properly, a great quantity of air can be pressed into a very small space. Of course the crowding requires considerable pressure, so that when a great quantity of air is crowded into a bottle or other small space, the confined gas exerts a great pressure against the sides in its endeavor to escape.

The amount of pressure air is capable of exerting, on the walls of a strong vessel into which it has been forced, may reach a value as great as 14,000 pounds or more to the square inch, or a pressure considerably over 900 times greater than the ordinary atmospheric pressure. Such a mass of crowded, compressed air is not unlike the genie in the bottle trying to escape, but unable to do so because the material of the bottle holds together with a force greater than that which is endeavoring to tear it apart. In this sense the seal of the great Solomon keeps the genie in the bottle. If such a bottled genie be permitted to rush out, he is capable of doing useful work, provided his powers are intelligently directed. Otherwise, he may work great havoc.

But the caged genie is not always shut up in a copper bottle. There is an imprisoned genie in every mass of gunpowder, dynamite, nitro-glycerine, or other high explosives. Here the seal of the great Solomon, although sufficiently strong to keep the genie in captivity, is only a little stronger than the genie himself, so that it requires but a slight increase in his strength in order to permit him to escape.

To make my meaning clearer, let us take the case of a quantity of gunpowder. This material consists of an intimate mixture of three solid substances, charcoal, sulphur and nitre or saltpeter. Each of these may remain in a solid condition for an indefinite time, but when the temperature is raised by means of a spark of fire the chemical attractions that exists between them for one another, are sufficiently increased to permit them to rush into combination and thus form great volumes of highly heated air or gases. When these gases are liberated in a confined space, as in the chamber of a gun, or at the bottom of a blast hole, the pressure they produce increases so rapidly as to hurl the projectile from the gun, or to rend the solid rock in which the blast hole has been bored.

An ingenious plan was employed at a colliery in England a number of years ago, for mining or blasting coal by means of cartridges, the explosive force of which was not gunpowder or nitro-glycerine, but compressed air.

There is considerable difficulty in keeping the air, in the galleries of coal or other mines, sufficiently pure for breathing, so that various methods are necessary for constantly renewing it. Now when the blasting is done by the use of gunpowder, nitro-glycerine, or dynamite cartridges, the noxious gases produced by the explosion vitiate the air of the mine and render it unfit for breathing. Considerable time is, therefore, lost by the miners in waiting for the removal of the foul air and its replacement by fresh air. This difficulty is entirely avoided by the use of compressed air cartridges. Let us, therefore, try to understand the operation of these cartridges.

Compressed air cartridges consist of strong cast-iron tubes twelve inches long, a little over three inches in diameter, the walls of which are slightly over half an inch thick, and therefore having a bore of nearly two inches in diameter. These cartridges are filled with compressed air at a pressure of nearly 10,000 pounds to the square inch.

The compressed air cartridges were employed in the blasting of coal by being pushed into holes bored into the undercut coal wall. Each cartridge had a small pipe attached to it somewhat like the fuse wire of the ordinary cartridge and were tightly tamped in the same manner as gunpowder cartridges. They were burst as follows: air at a pressure of about 14,000 pounds to the square inch was passed from a strong reservoir through a wrought iron tube connected with the compressed air cartridge. On the higher pressure air being admitted into the cartridge an explosion occurred, and the compressed air rushing out did work just as would the explosion of gunpowder or other explosive. In some of these mines a wall face of from five to six tons of coal was thrown down at each blast.

With this system of mining by compressed air, the miners were able to carry on their work almost continuously, having only to momentarily shield themselves from the flying coal; for, the air of the mine, instead of being vitiated by the explosion, was cooled and rendered purer than it was before. In addition to this the danger of igniting by the fire of the explosion the mixtures of explosive gases, so apt to be present in coal mines, was entirely obviated.

You will remember in the chapter on the "Wonders of Atmospheric Pressure," the illustrations given of the great power possessed by the pressure of a single atmosphere in moving weights or doing other work. This pressure is somewhat less than fifteen pounds to the square inch. The amount of work it is capable of doing as in raising water is limited to a height of about thirty-two feet, as was found in the time of Galileo. But when, as in the case of highly compressed air, the pressure amounts to several thousand pounds to the square inch, you can see how easy it would be to raise water from almost any depth.

There are various methods employed for compelling the genie of the bottle to do useful work as he rushes out in his eagerness to end his long captivity. Sometimes the escaping air is caused to act directly on the work that is to be done. This is the case in the pneumatic gun in which air, under great pressure, is permitted to enter the gun-barrel back of the projectile and thus force it out of the gun with a high velocity. Compressed air is employed for forcing projectiles from guns, not only so much for the purpose of taking the place of ordinary gunpowder or other explosives, but for throwing projectiles filled with dynamite or other high explosives that would be dangerous to handle with gunpowder. The greater ease and certainty with which compressed air can be regulated and controlled, makes it possible to project highly explosive cartridges containing large quantities of high explosives with a safety that would be impossible if gunpowder were employed.

In the pneumatic dynamite gun, invented by Lieutenant Zalinski, an air pressure of 500 pounds to the square inch was employed. Under this pressure a dynamite cartridge was fired with great precision a distance of one and a quarter miles. The gun had a bore of two inches and a length of twenty-eight feet.

Another gun, invented by Zalinski, employed air at a pressure of 1,000 pounds to the square inch. This gun had a bore of eight inches, a length of sixty feet, and was capable of throwing the dynamite projectile a distance of two miles.

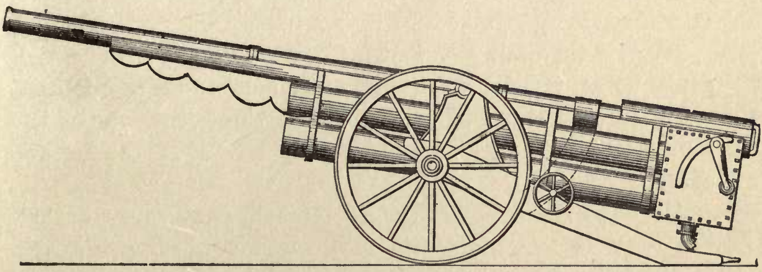


FIG. 22. GRAYDON'S PNEUMATIC DYNAMITE GUN

A still larger gun, built by Zalinski, employed an air pressure of 1,500 pounds to the square inch. This gun had a bore of eight inches.

In order to insure the discharge of the dynamite in the projectile, Zalinski invented an electric fuse, in which the discharge is exploded by means of an electric battery that ignites a detonator on the shell, by closing the circuit on the impact of the shell on striking.

Another form of pneumatic dynamite gun has been invented by Lieutenant Graydon, of the United States Navy. This gun is much shorter than the Zalinski gun and is operated by a pressure of some 3,000 pounds to the square inch. The compressed air required for firing the gun is contained in high-pressure bottles or cylinders placed on the gun carriage under the gun, as shown in Fig. 22. So here, as you will see, the bottled genie is taken to the battlefield along with the gun, and is permitted to escape and vent his anger on the enemy.

Another case in which the compressed air is permitted to act directly on the work that is done, is seen in the method employed for the transmission of mail matter through metallic tubes buried in the streets of a city; as well as in the somewhat similar method employed in the great department stores for carrying small carriers containing cash from the different counters of the store, to a central office from which the proper amount of change, etc., is returned in this case through the same tube by air pressure.

There is something so pleasing in the thought of the caged genie being put to work in carrying mail matter underneath the streets of our cities, that I think you will be interested in hearing in a general way how this work is accomplished.

Although Dr. Papin, in the seventeenth century, suggested the possible use of compressed air for pneumatic tube transmission, yet the first successful application of this system was not actually put in operation until the year 1853, when a pneumatic tube, about the eighth of a mile in length, and an inch and a half in diameter, was first operated in London. This system was so successful that it has been extended in this city until there are now about thirty-four miles of pneumatic tubes under the streets connecting some forty-two stations. The first tube was operated by exhausting the air in front of the carrier, the name given to the box or carriage in which the mail or other matter is placed. The advantages, however, derived from the use of compressed air have proved to be so many that this is now generally employed in preference to a partial vacuum.

In 1893, a pneumatic system of tube transmission for mail matter was installed in the city of Philadelphia between the main post office at Ninth and Chestnut Streets, and the Bourse Building, between Fourth and Fifth Streets, and Market and Chestnut Streets. Here, besides the tube that connects the main post office with the Bourse, a loop was provided for the return of the empty carriers. The carriers are shot from the Post Office to the Bourse in sixty seconds and require fifty-five seconds for the return trip. The carrier is only eighteen inches long, but since it can hold 200 letters, and these can be despatched at intervals of six seconds, the capacity of the tube reaches 240,000 letters an hour, its speed being about fifty-two feet a second. You can get some idea of the value of this system when you learn that in the first four years of its use there were carried more than 35,000,000 letters, and that during this time there was but a single serious interruption caused by an obstruction in the tube.

In a similar system that has been subsequently introduced into New York City where a line has been built between the Produce Exchange and the Main Post Office, a distance of about 4,000 feet. This line consists of two tubes, eight inches in diameter, placed side by side, about five feet below the surface. With these tubes a working speed of thirty miles an hour is obtained. The pneumatic tubes are made of cast iron with a smooth interior finish, the bends consisting of seamless brass tubes. The carriers weigh nearly fourteen pounds and can hold about 600 ordinary letters each.

During the blowing of strong winds, on the seashore and other places, fine particles of sand are carried with the moving air with such force that when they strike against the face or other exposed portions of the body they are capable of giving stinging or cutting blows. It is quite possible that you may have experienced this while walking along the sea beach. If so you will remember how you were stung as the small particles of sand struck you.

It is no wonder that these particles of sand gave stinging blows when they struck your hands or face; for, if they are permitted to fall on the surface of a piece of polished window glass, or on a glass tumbler, they will actually cut or scratch the hard glass wherever they strike it, thus causing it to lose its polished surface and become what is called ground glass.

If you happen to be at the seashore, some time during a high wind, when the sand is being blown through the air with fairly considerable force, you can try a very simple experiment which will prove the power of moving particles of sand to cut or scratch glass. Cut a stencil in a sheet of paper with the initials of your name or with any other design you may wish, and paste it on the outer surface of a glass tumbler or on one side of a plate of glass, being careful to leave no paste on the places where the paper has been cut away and the glass left uncovered. Place this on the beach in such a position that the particles of moving sand can strike fairly against it. Wherever the sand strikes the uncovered glass it cuts little chips in its surface, thus causing it to lose its polished surface and assume the appearance of ground glass; but where it strikes the paper, no effect is produced on the glass underneath. If, therefore, the glass be removed after a certain time, and the paper washed off its surface, the initials or the other design cut in stencil form on the paper, will be found clearly marked on the glass, while all the rest of the surface will retain its polished appearance.

This power of moving sand particles to cut or grind hard surfaces has been practically employed in a process known as the *sand-blast process* for cutting or ornamenting glass, granite, marble, or other hard stones, as well as for iron or other metals.

In the sand-blast process the escaping genie is made to do the useful work of cutting or shaping these substances while rushing out of the bottle. Let us see how this is done.

Suppose a stream of air, under a pressure varying from a few pounds to fifty pounds or more to the square inch, is caused to carry with it small particles of hard materials, such as ordinary building sand, sand taken from a sea beach, sand consisting of particles of chilled iron, or of particles of emery; and that this blast of air, with its cutting particles, is permitted to strike against the surfaces that are to be cut, say pieces of building stone, or metal, protected from the action of the blast at all places that are to be left uncut, but directly exposed at all other places. Under these circumstances, the particles of sand, striking against the uncovered surfaces, begin to cut them with great rapidity. Only a few moments are required completely to remove the polish from the surface of glass. If the action is continued for a longer time holes can readily be cut through glass, stone, or even through hard iron or steel.

It may surprise you that these small moving particles are able to do the work so rapidly; for, owing to their very small size, their energy, or their ability to do work, is necessarily very small even when they are moving with great velocities. There are two reasons why they are able to do such efficient work; i. e., the very small surfaces on which they act, and the rapidity with which they give up the energy they possess to the surfaces they strike. Although the action of each grain may be very small, yet if it possesses any action at all, the number of successive particles that strike the surface in a given time is so great, often as many as 5,000,000 per minute, that there is produced a rapid cutting.

The sand-blast process is employed for a great variety of purposes, such as cutting designs in glass; cutting holes or ornamental fretwork in sheets of glass or marble; cleansing the surfaces of castings of iron or other metal; sharpening files; cutting carvings or inscriptions in relief on stone; cleansing the surfaces of marble, granite or brick buildings; removing old paint or dirt from iron work, etc.

A very beautiful application of the sand-blast process is that employed for cutting or etching a photograph on the surface of polished plate glass. This is done as follows: The surface of the glass is covered with a thin layer of gelatine, which has been rendered sensitive to light by treatment with bichromic acid. The plate is dried in the dark, and a photographic picture printed on it by any suitable means. The portions of the plate that are acted on by the light are thus rendered insoluble in hot water. The plate is then developed by careful treatment with hot water, which removes the gelatine from all the parts that have not been acted on by the light, thus exposing the polished glass surface. The plate is then carefully dried and exposed for a few moments to a sand-blast and thus has cut in its surface a photographic picture on all the exposed portions. It is evident that either a negative or a positive picture can be obtained in this manner according to whether a positive or a negative photograph has been employed for printing the picture on the gelatine plate.

Compressed air is also employed as a simple but efficient means for applying whitewash or paint to extended surfaces.

You can understand how easy it would be to apply a coat of whitewash or paint, to the entire outside of a building, by causing a stream of air containing fine particles of the whitewash or paint to fall as a spray against the surface to be covered. Such a process would require much less labor than the tedious method of employing a paint brush operated by hand. A jet of spray will carry the paint into the cracks and crevices of the work far better than could a hand-operated brush. Moreover, besides being far more efficient, spray painting is more rapid than ordinary hand work. Of course, such a process is only suitable for such work as bridges, the painting of cars or for cases where the entire surface is to be covered, since if an attempt were made to apply whitewash or paint in this manner to the walls or ceiling of a room it would be necessary to first protect the woodwork and other parts that are not to be painted, and this would require so much work that the ordinary process is preferable.

Another application of compressed air is for cleansing the dust from carpets, or other objects in a room; from car seats, or from many of the other places where dust can settle. Since, as will be seen in the chapter on the "Dust of the Atmosphere," it is air currents that carry the dust particles into nooks and crannies, there is a peculiar fitness in employing the same force for carrying them away again.

It may have seemed to you to be a very simple thing to obtain some of the high air pressures employed in the process of mining coal, or in the operation of pneumatic guns, by continually forcing the air into a small space until the desired pressure is reached. It is necessary, however, while this action is taking place to provide means for carrying away the heat produced during compression. You may form some idea of the necessity for getting rid of this heat when I tell you that if air was continuously pumped into a reservoir, until the pressure reached, say 200 pounds to the square inch, the air would become hot enough to set fire immediately to woodwork or to melt metallic lead. Devices, therefore, called *coolers*, are employed in the compression of air where great pressures are required.

Instead of obtaining the desired pressure by a continuous compression, the work is done in successive stages. In other words, after a certain pressure has been reached the hot air is passed through a device called a cooler. This consists of a chamber containing a number of copper tubes through which cold water is passed. The heated air is cooled as it passes over the outside of the copper tubes. When the final pressure is obtained by two successive compressions, with a single cooler, the process is called a *two-stage compression*. For pressures of from 2,000 to 3,000 pounds to the square inch, a *four-stage compression* is necessary.

Sometimes, when the genie rushes out of the bottle which has imprisoned him, he is caused to work or drive various tools known as *pneumatic tools*. These tools are operated on a principle not unlike that of the steam engine in which a piston is caused by the pressure of the air to move rapidly to-and-fro and thus operate various devices. An example of pneumatic tools is to be found in the *pneumatic hammer*, such as is employed for heavy *chipping*, for *calking* or for *riveting*. Pneumatic hammers can be made to give from 1,500 to 2,000 blows per minute, or even a greater number. Pneumatic hammers have also been designed for the cutting of stone or for sculptor work generally. Pneumatic tools have also been devised for drilling blast holes in rocks, as well as for the drilling of holes in metals or wood or other work.

I have thus given you a brief account of but a small part of the work which the bottled genie has been compelled to do for man. There are many other kinds of work he can perform, but it will not be practicable to give you any further account of such work by reason of our limited space.

When the atmosphere is subjected to a very considerable pressure and, at the same time, means are taken not only for removing the high temperature that is produced by the compression, but at the same time to reduce and keep the compressed air at a very low temperature, the air loses its gaseous condition and becomes changed into a liquid closely resembling water, except that its color is light blue. Liquid air when relieved of the pressure so rapidly evaporates that it begins to boil, and thus produces a very intense cold. In this manner temperatures as low as 346° below the zero of the Fahrenheit thermometer have been obtained.

Some very curious effects are produced on certain food products when cooled to exceedingly low temperatures by the evaporation of liquid air. Meats, for example, become so hard that when struck by a hammer they ring like steel and are readily broken into a fine powder, as would a piece of glassware or porcelain. The chopped pieces of cabbage in sauer-kraut become as hard as flakes of mica, and the mass holds together so firmly that it can only be removed from the barrel or tub in which it has been stored, by a chisel and hammer.

Liquid air possesses many curious properties and has been applied to a number of practical purposes. Its further discussion, however, properly belongs to the "Wonder Book of Heat," in which it will be described.

CHAPTER VI

THE SOUND WAVES OF THE ATMOSPHERE

There are various phenomena, constantly going on around us, that are dependent for their existence on differences in the presence of the atmosphere. Some of the most important of these are the phenomena of sound. Were our earth's atmosphere removed and other means provided for our continued living, practically all sounds would at once cease and there would be an eternal silence over the earth.

This is so interesting a matter that we will take some little time to explain it.

Three things are necessary for the production of sound: a vibrating or sonorous body; a medium capable of being set into to-and-fro motions or vibrations, and an ear connected with the brain of an animal. The medium usually consists of the air or atmosphere. In it the sonorous body produces sound waves that move outwards in all directions, and, provided they affect the ear and through it the brain, produce the sensation of sound.

The atmosphere, however, is not the only medium in which sound waves can be set up. Such waves may also be produced either in liquids or in solids.

While a full description of the phenomena of sound belongs properly to the " Wonder Book of Sound," yet so many of the wonders of the atmosphere are due, either directly or indirectly, to the action of sound waves, that it will be necessary before describing these wonders to give a brief explanation of some of the elementary principles of acoustics.

Let us suppose that a sound is produced, such as by striking a bell, hung in the middle of a large empty room. When the clapper or hammer strikes the bell, what happens is very simple. The walls or sides of the bell begin to shake to-and-fro, and, striking the air particles, move them away from the sides. When this motion reaches the ear of an observer, a sound is produced.

You must not suppose, however, that the air particles thrown off from the bell continue to move straight forward until they reach the observer's ear. On the contrary, they only move away from the sides of the bell for a comparatively short distance, when, striking against other particles of air, they give up their motion to them, and then come to a state of rest. In the meanwhile, the particles of air last set in motion move the particles around them, and these the particles around them; and this is continued until a series of pulses or waves is set up in all the air in the room.

I will not take space to explain more fully to you the true nature of the motion of the air particles in sound waves. In reality, this motion is more complex than you might suppose from the preceding explanation. There is, however, a simple experiment which will enable me to briefly show you the character of the motions of the sound waves.

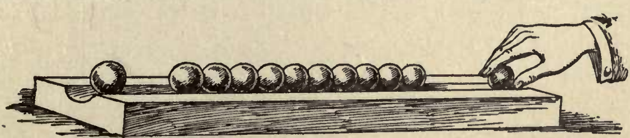


FIG. 23. EXPERIMENT WITH TWELVE IVORY BALLS

If you will examine Fig. 23, you will see a row of twelve ivory balls resting in a smooth groove in a block of wood or stone, so that all the balls touch one another. If now, one of these balls be taken in the hand, as shown in the figure, and thrown against the ball nearest it, the blow or impact will be transmitted through the remaining balls. If the experiment is well performed, you cannot see any of the other balls move, except the last ball, which suddenly flies away from the rest. It is evident, however, that in some way or other the force of the moving ball has been transmitted through the row of balls to the last ball, which flies off as a result of the blow it has thus received.

What has taken place is as follows: when the first ball strikes the ball nearest it, it gives up its motion to it and comes to rest. The second ball gives up the motion it thus receives to the next ball and comes to rest, and this is repeated successively through the balls, each ball giving up its motion to the one next to it and then coming to rest. When, however, the twelfth ball has received the blow from the eleventh, there being no ball to which it can give up its motion, it moves away from the others.

Now the sounding bell sends a pulse or wave through the particles of air around it in a similar manner. As the sides move outwards, they throw the particles of air around them outwards. These particles, striking the particles of air in front of them, give them their motion and then come to rest, and this motion goes on through successive air particles until the particles of air that fill the cavity of the ear of an observer are caused to move onward until they strike against the *tympanum*, a tightly stretched drum-head in the ear, and shake it. This motion is transmitted to the brain, thus producing the sensation of sound.

If you have any difficulty in picturing to yourself what takes place among the successive particles of air when a sound wave, or pulse, is passing through it, you will, I think, be aided if I describe a simple but beautiful experiment suggested by Professor Tyndall. Air particles, of course, are so small that you cannot see them; nor, indeed, could you at a distance see very distinctly the separate ivory balls. Suppose we represent each air particle, or ivory ball, by a boy. In the air these particles extend in all directions around the bell; but what is true of any single set of particles that reach in any direction outward from the bell, will be true of all similar sets of particles reaching in any other direction. Therefore, let us take only five of such particles and represent them by the five boys placed as shown in Fig. 24. Here each boy's hands rest on the shoulders of the boy in front of him. Suppose, now, the boy A, at one end of the line, receives a sudden push against his shoulders in such a direction as to move him against B. A will give up this motion to B, and will come to rest standing in an upright position. B, in a similar manner, now imparts his motion to C, and then comes to rest; and this goes on until D, the fourth boy, gives his motion to E, who, having no boy in front of him, is thrown forward.

Now suppose these boys represent the particles of air through which a sound pulse is passing, E being the air

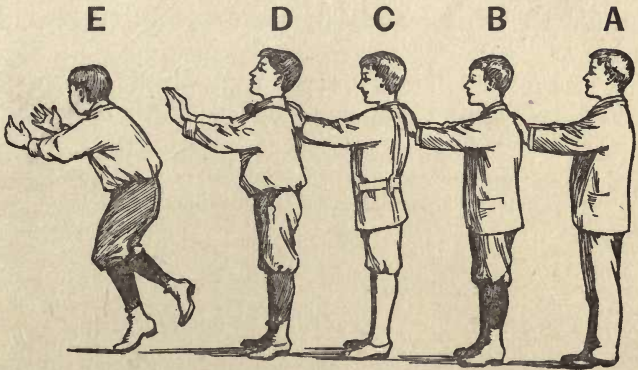


Fig. 24. Experiment with Five Boys

particles near the drum of the ear. As the particles at E are thrown forward, they strike the drum, making it shake; and this shaking, being transmitted to the brain, produces a sound.

If, instead of having twelve ivory balls as shown in Fig. 23, we have 100, or even 1,000, the motion would be transmitted through them in the same manner, and as soon as the last ball was reached, it would be moved forward. The time required to do this, however, would be greater as the number of balls increased, for time is required for the transmission of a sound pulse.

Coming back to the illustration of the row of boys, I do not think you will have any difficulty in understanding that the time required to transmit the pulse or push of the last boy will vary considerably with the manner in which each boy transmits his push to the boy on whose back his hands are resting. If each boy gives up his motion sluggishly, it will require a much longer time for the motion to be transmitted through all the chain, than if each boy gives up his motion quickly. In other words, the time required for the transmission of a pulse through a row of particles will vary with the nature of the particles. Very elastic balls, such as a series of ivory, or glass balls, will transmit a pulse much more rapidly than a series of wood, or cork balls.

There is another interesting experiment, which I believe was also first proposed by Professor Tyndall. This experiment

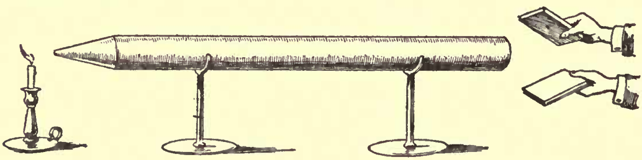


FIG. 25. LIGHT EXTINGUISHED BY SOUND PULSE

shows the manner in which a sound pulse is sent through the tin tube, shaped as shown in Fig. 25, and supported on a stand. Now, this particular tube is fifteen feet long. As you will see, it is open at both ends; the opening at one end, however, is the entire width of the tube, while the other end has open only the small part of a cone that is attached to it. Suppose, now, a lighted candle be placed with its flame near the opening at the small end, and a loud sound is made at the larger opening in anyway, as by clapping two pieces of board together. The sound pulse transmitted through the tube will now instantly extinguish or blow out the candle-flame.

This extinguishment of the flame is not, as you might suppose, due to a current of air blown though the tube by the striking together of the pieces of wood; for, if the inside of the tube be filled with smoke, and the candle-flame be relighted the clapping together of the boards will, as before, instantly extinguish the flame, but no smoke will be seen escaping from the small end as would have been the case had the air been actually forced through the tube.

In the case of the ivory balls, the distance the last ball is thrown away from the others will depend on the amount of force that is used. If the first ball is thrown against the other with more or less force, the last ball will be thrown off to a greater or less distance. Then, too, if the same force be employed, the last ball will be thrown off with less force if the pulse has passed through 100, or 1,000 balls, than if it had only passed through twelve balls.

Of course you know the sound of a bell is greater when you are near it than when you are a great distance from it; for, since the bell sets up sound waves in all the air of a room, if the room is large the particles of air furthest from the bell will have received their motion by transmission through a very great number of air particles. Therefore, the force with which the particles strike against the drum of the ear is comparatively feeble, and hence the sound produced is not very strong.

Suppose, instead of permitting the sound waves to spread in all directions through the air of a room, they are passed through a closed tube, smooth on the inside, so as to decrease the friction. The tube shown in the preceding experiment will answer very well for this purpose. It is, as you will remember, fifteen feet in length. Now, if I stand at a distance of fifteen feet from a person and say something to him in a faint whisper, he will be unable to understand me, since the sound pulse has not only passed through the air of the room in the straight line between us, but also in all other directions. If, however, this person places his ear at the small end of the tube, and I whisper at the larger end with the same strength as I did before, he will be able to hear all I say, but no one else in the room can hear; for all the energy with which I speak is now limited to the air inside the tube, so that the last particles that are shot off from the end of the tube strike the drum of his ear with considerable force. Try to imagine how many people might be placed at a distance of fifteen feet with my lips as centre, and that I speak just loud enough for all these people to hear. I do not know how many people can be placed in such a position, but let us suppose, simply for the sake of convenience, that there are a 100 or more, and I speak loud enough to make all the people hear. Then, if I speak equally loud in the tube, all this sound would now be concentrated on a single ear, and, as you can easily understand, the sound produced would be much louder; therefore the distance through which conversation could be held by means of a tube would be very much greater.

This is the principle of what is called a *speaking-tube.* A speaking-tube consists merely of a smooth tube, generally of tin, connecting two different parts of the house. The person holding his ear near one end of the tube can distinctly hear whatever a person whispers in the other end.

Provided the tubes are air-tight, are smooth on the inside, and do not change their direction too frequently or abruptly, it is possible to readily hold conversation in a faint voice over considerable distances. The French philosopher, Biot, made some interesting experiments with the water-pipes of Paris before the water was turned on, and found that there was no difficulty in holding conversation in a low tone over a distance of about three-fourths of a mile. But if tubes are to be used for great distances, their diameter must not be very great, and the insides must be kept very smooth.

You can try an amusing experiment with a fairly wide India rubber hose, provided the inside is smooth. Pass such a tube out of the window of a third story room into the yard. If the hose is not long enough, the second story will do, although the third story is preferable. A person holding his ear at either end of this tube can distinctly hear what is whispered at the other end; and a conversation can easily be carried on through it.

By placing a small, conical tube inside a human figure, the sounds from the yard will appear to come from the mouth of the figure, so that it will seem as if it was speaking; and, since it would be quite possible in this way to transmit sounds through distances of many hundred feet, you can easily understand what very odd effects could be obtained.

But air is not the only medium through which sound waves can be sent. Any other elastic medium can be employed for this purpose. For example, water answers admirably. Some time when you are in swimming, hold your head near the water, so that one ear is immersed; or, still better, dive under the water and have a companion strike two stones together and you will be surprised how distinctly the sound waves, or pulses are transmitted through the water to your ear.

You must be careful, however, in trying this experiment, not to be too near the source of the sound, and to caution the person making the sound not to make it too loud, since water is so good a conductor of sound that the drum of the ear might be seriously injured by the intensity of the sound waves. It would be very dangerous to have your head partially or completely under the water when submarine blasting is going on. Under such circumstances, the chances for losing your hearing would be very good. Indeed, as you are probably aware, the pulse produced by the explosion of dynamite under water is so severe, that it generally partially stuns, or completely kills all the fish in the neighborhood.

Sounds can also be transmitted through solids. If you place an ear against one end of a long, wooden bench, you can distinctly hear the scratching of a pin against the other end. So, too, when the wind is blowing, if you hold one ear firmly against the side of a wooden telegraph pole, you will hear sounds like those of a great Æolian harp, that are caused by the wind striking the telegraph wires.

The string of a kite can also transmit sounds. Major Abbot describes a form of musical kite that is common in certain parts of Central Asia. This kite is easily made, and I would advise you to surprise your friends with one. The kite consists of a square, formed by two diagonal sticks firmly connected at right angles, and the edges connected by means of a tight string, thus forming the four sides of a square. A piece of paper is then pasted over the surface in the usual manner. The string for raising the kite is attached to a loose string, the ends of which are tied firmly to the ends of the upright diagonal. A tail, of the usual form, is then attached to the lower extremity of the kite, then one of the cross-sticks, say the horizontal one, is bent back like the string of a bow by means of a piece of catgut. This piece of catgut must be made so tight as to produce a musical sound when struck by the wind. When such a kite is raised, the musical note produced by the piece of catgut is transmitted to the ground by the string employed for raising the kite. In order to strengthen the tone of the catgut, the end of the string employed for raising the kite must be firmly attached to the top of an empty starch- or soap-box that has been securely fixed to the ground.

Sound is readily transmitted through the ground. Indians, and woodsmen generally, can often hear the approach of an animal, or an enemy, by listening with an ear close to the ground.

A medium is necessary for the production and transmission of sounds. This medium is ordinarily the air, so that, in the absence of air, all ordinary sounds would instantly cease. The natural philosopher, Hawksbee, in an experiment made before the Royal Society of London, proved that all sounds disappear in a vacuum. He suspended a bell inside a glass jar placed on the plate of an air-pump, so that, while the jar was being exhausted, the bell would be sounded. As the air was gradually removed from the glass, the sounds produced became more and more feeble until, when nearly all the air was drawn from the glass, the sounds almost entirely ceased.

Various forms of apparatus have been devised for the purpose of repeating Hawksbee's experiment. In one form the bell mechanism is hung on strings, so that some of the vibrations would be communicated to the outside.

A very simple observation will convince you that time is required for the transmission of sound waves. When you are standing near a person who is talking to you, so very short a time is required for the sound waves to pass from the lips of the speaker to your ears that the transmission may seem to be instantaneous; but if you are at a considerable distance from the place where sound waves start, as, for example, when you see a man at a distance strike a blow with a hammer, you will see the blow struck some time before you hear the sound of the blow. A still better example is the firing of a cannon, for you can see the flash long before you hear the report.

Sound waves travel through air when at a temperature of melting ice, with a speed of about 1,090 feet a second. As the temperature increases, the velocity of sound slightly increases. The velocity of sound in liquids is much greater than in air, the velocity in water being about four and a half times that in air. The velocity of sound in most solids is greater than in water.

There is a matter connected with the reflection of sound waves that I will endeavor to explain to you. It is much easier to speak to an audience in a room than it is to speak in the open air; for, in the room, the sound waves coming directly from your mouth reach the ears of the audience at almost the same time that the reflective waves do from the walls and the ceiling. When the distance between the walls reflecting the sound and the position occupied by the speaker is not too great, these reflected sounds, reaching the ear of the audience only slightly after the direct sounds, tend to prolong and strengthen them. In other words, the speaker's voice is said to be strengthened by *resonance.*

You may, possibly, have been surprised when you held a hollow shell to your ear to hear murmuring sounds not unlike those produced by the waves beating on the shores of the ocean. This is not due, as some ignorant people assert, to imprisoned sound waves, but to the strengthening of feeble noises in the atmosphere by the resonance of the shell.

CHAPTER VII

ECHOES

You have undoubtedly heard echoes, and been both pleased and amused at the accurate way with which they repeat sounds. As you know, these sounds may be either spoken words, or the words of a song, or of some musical instrument.

An echo never originates sound. It only repeats what it hears. Moreover, it is only able to make one hear the last portions of these sounds.

The ancients believed that echoes were produced by a nymph named Echo, a daughter of Air and Earth. At one time they declared poor Echo could talk like other people. Indeed, she was so fond of talking that she got into trouble, for she was employed by Jupiter to keep talking to his wife, Juno, so as to prevent her from watching him too closely. Juno, discovering what Echo was trying to do, punished her by forcing her, whether she wished to or not, to repeat the last few syllables of anything that had been uttered in her presence. She could not, however, speak anything else. You can understand how great a punishment this must have been to a young lady who was especially fond of hearing herself talk.

I am sure you will be surprised at some of the wonders of the atmosphere that are caused by echoes. Let us, therefore, endeavor to understand just how echoes are produced.

An echo in sound is what an image is in light. If a lighted candle be placed in front of a plane mirror you will see an image of the candle as far back of the mirror as the candle is in front of it. When the rays of light, coming from the candle, strike the surface of the mirror, they are flung back, or reflected, and entering the eyes of the observer, produce an image that appears to be back of the glass.

In the same manner, if you stand in front of a good reflecting surface of fairly considerable size, such as a high, perpendicular cliff, and speak, shout, or sing, the last few syllables will be repeated, and will appear to come from some point back of the cliff. This sound will be similar to the sound you made; that is, will be the same words of the song, the same notes of the musical instrument, or the same words that were spoken. This is because the sound waves that strike the surface of the cliff are reflected, or flung back, and entering your ears, produce an echo.

That sound is capable of being reflected like light, can be shown in a variety of ways. Professor Tyndall showed the following experiment at one of his lectures. A large, concave mirror was placed facing an electric lamp in a distant part of the lecture hall. When the lamp was lighted, the rays falling on the mirror were reflected so as to collect at a focus in front of the mirror. The position of this focus was seen in a bright cone of light received on a cloud of smoke in front of the mirror. In this way the position of the focus was readily discovered.

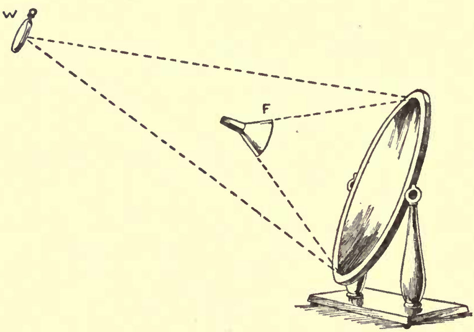


Fig. 26. Focus of Concave Mirror

Then, remembering the position of the focus, let us suppose it at W, in Fig. 26, if a person stood in front of the mirror with one of his ears at this focus, he would have no difficulty in hearing the ticking of a watch placed as shown in the figure; and if, in place of the ear, he employed the tube shown at F, he could hear it more distinctly.

A reflecting surface, however, is not able to produce a distinct echo, unless it is far enough away from the place where the sound starts to permit a sufficient time to elapse between the direct and the reflected sounds, for each to be heard separately. Unless this distance exists, the reflected sounds affect the ear before all the direct sounds have died away, and thus fail to be heard separately.

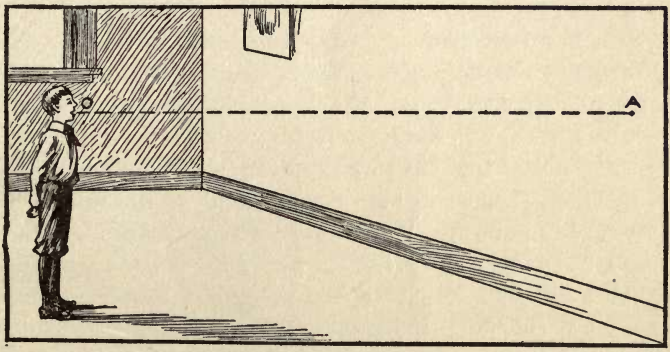


Fig. 27. Production of an Echo

I will endeavor to explain to you why it is that the source of sound must be situated at a certain distance from the reflecting surface in order to produce echoes. Suppose, for example, the boy represented in Fig. 27, is standing at O, in front of a reflecting wall A. To enable him to hear an echo, he must be at a certain distance from the reflecting surface. We will suppose that he pronounces five syllables a second, or about one-fifth of a second for each syllable.

Then, taking the velocity of sound at say 1,100 feet per second, or at the rate of 110 feet per syllable, if the reflecting surface is fifty-five feet from the source of sound, the sound waves from the speaker will pass through a distance of 110 feet in the fifth of a second, or fifty-five feet in going, and fifty-five feet in returning from the reflecting wall. If, then, a person in front of such a wall stops speaking, he will be able to hear a distinct echo of the last syllable uttered.

In a similar manner if the reflecting surface is two, three, four, five, or six times further than the distance necessary to produce an echo of a single syllable, he will be able to hear three, four, five, or six distinct syllables as echoes.

Almost any good plane surface is capable of reflecting sound waves, and thus produce echoes. Clouds can act in this manner. When the sky is free from clouds, the report of a large gun is heard on a plain as a short, quick sound. When, however, there are clouds in the sky, the echoes returned are not unlike the rolling of distant thunder. The unequal under surface of the clouds and varying distances, together with the consequent double and treble reflection of the echoes, combine to produce and prolong the roll.

A water surface is also an excellent reflector of sound waves. Echoes produced in this manner are especially heard by people in balloons.

Sometimes the sail of a vessel, bellied by the action of the wind, acts like a huge, concave mirror, and, bringing faint sound waves from a large surface to a focus, permits them to be heard by a person standing near such a focus, when, to any one standing outside the focus they are unheard. A story is told of a sailor who, going aloft to reef one of the sails of the vessel, reported, on coming down to the deck, that while standing in a certain place in front of one of the main sails, he distinctly heard the sound of bells, and that, from their sounds, he believed rejoicings were going on. The ship was then at a considerable distance from any land, so that it would have been impossible to hear such bells directly. The captain, however, entered the story in the ship's log, and afterwards learned that, at the time the sounds were heard, rejoicings were going on in a distant city on the coast. The explanation was that the sail acted like the concave mirror employed in Tyndall's experiment with the ticking watch, so that the faint sound waves falling on the extended surface of the sail were brought to a focus, and, entering the ear of the sailor, were capable of reproducing the sounds of the distant bells, possibly by means of a double reflection from cloud to sail.

There are records of some very wonderful echoes. In Woodstock Park there is a reflecting surface that repeats seventeen distinct syllables by day and twenty by night. There is another on the banks of the Lake del Lupo, above the water-falls of Terni, that repeats distinctly fifteen syllables of sounds uttered in certain places.

It is by no means an uncommon occurrence that the reflections of sound waves from large curved surfaces are brought to a single focus, and that faint whispers uttered at certain places can be heard by an ear placed at the focus. These places are called *whispering galleries*. Many instances of whispering galleries are found in buildings where the reflection of sound waves from the dome-shaped ceilings of the room, or from the vertical walls of octagonal buildings, the sound waves falling on a considerable area, are brought to a single focus. In such places a faint whisper when uttered at one point can be distinctly heard at a distant point or focus, while absolutely inaudible at any intermediate points.

Whispering galleries are especially found in rooms with dome-shaped ceilings, where a gallery extends around the lower part of the dome. In such cases, faint whispers uttered at one part of the dome can be distinctly heard at a focus on the opposite side from where the speaker is standing. Such whispering galleries are common in the rotundas of some of the capitol buildings in different parts of the United States.

In the octagonal gallery of the Cathedral at Gloucester, a faint whisper can be heard across the church, over a distance of seventy-five feet.

It is said that Dionysius, the Tyrant of Syracuse, had a dungeon constructed in the quarries near the city, the walls of which were so arranged that the faintest whispers could be heard in the adjoining room by the tyrant himself or by some of his emissaries. It was the habit of Dionysius to put several prisoners in this dungeon, and thus obtain evidence against them from their own mouths, which resulted in their being condemned to death. This dungeon received the appropriate name of the *Ear of Dionysius.*

It is not, however, generally the case that whispering galleries are purposely constructed. On the contrary, their existence frequently remains unknown for a long time, until discovered accidentally. Sir John Herschell, the astronomer, tells the story of a whispering gallery that was accidentally discovered by a gentleman in a cathedral in Sicily. Here the sound waves of the voice produced at one of the confessional boxes, being reflected from the curved ceiling of the church, were brought to a focus in a distant part of the building. This man was ungentlemanly enough to listen to the conversation, and was very properly punished one day when bringing a friend with him to enjoy this questionable pleasure, for he was horrified to see his wife kneel at the confessional box, and was far from being either complimented or pleased with what both he and his friend overheard.

When an object is placed before a single mirror, only a single image is produced; but when placed between two mirrors that are inclined towards each other, a number of images are produced. This number varies with the angle of inclination between the two mirrors. When they are placed precisely parallel to, and facing each other, the number produced is, theoretically, infinite. Practically, however, the number of images seen is comparatively limited owing to the rapid decrease in the intensity of the light, until at last the images become so faint that they are invisible.

Now, in a similar manner, when sounds are produced between two parallel surfaces, repeated, or multiple echoes are produced, the same sound being repeated a number of times. This occurs when two surfaces are parallel and opposite to each other, as in the case of two opposite cliffs on different sides of a river, or the opposite walls of a large room.

In the case of multiple, or repeated echoes, a surprising effect is produced by the successive sounds as they are thrown to-and-fro between the opposite walls. It is by reason of the multiple echoes that the rumbling and rolling of thunder are heard as the sound waves are thrown repeatedly to-and-fro between the clouds and the ocean. This is especially so at sea on account of the excellent reflecting surface of the water.

Certain striking and beautiful effects of multiple echoes are produced in the Alps by the Swiss mountaineers, who manage to sing their songs in such a time that the reflected notes make an agreeable accompaniment to the air itself. In a similar manner the sound waves of the Alpine horn, reflected from the rocks of the Jungfrau, are at first heard unpleasantly; but, with successive reflections, they gradually decrease in their intensity and become more and more flute-like.

Another class of multiple echoes is to be heard in caves, or deep wells. Hartwig cites the case of a well in Carisbrooke Castle, 210 feet deep and twelve feet wide, the interior of which is lined with smooth masonry. The vertical walls are such good reflectors of sound that, when a needle is dropped into the well, it can be distinctly heard when it strikes the water.

CHAPTER VIII

THE COLOSSUS OF THEBES AND HIS MUTE COMPANION

In the neighborhood of the ancient city of Thebes there were two colossal figures facing the east, each of which was hewn out of a single stone. Though alike to all external appearances, one of them possessed this strange property. As soon as the rays of the rising sun fell on its lips, sounds could be heard apparently proceeding from its mouth, so that the statue was believed to be speaking to the sun. The other figure remained indifferent to the sun's rays, remaining mute at daybreak, noon, and sunset, as well as the rest of the twenty-four hours of the day. The speaking colossus of Thebes was known as Memnon.

As you probably know, Thebes was formerly the capital of Southern Egypt. This ancient city was situated in lat. 26° S. in a portion of the valley of the Nile near the Libyan Mountains.

Thebes appears to have been founded during the first Egyptian dynasty. No large buildings have been discovered that are older than those of the eleventh dynasty, or about 2500 B. C.

The word Memnonium means a place sacred to the memory of the dead. At a much later date, the Greeks consecrated the speaking statue to Memnon, the son of Eos, the Morning, and Tithonis, the Sun. Memnon, or Tithonis, was a Prince of Troy, and was, therefore, obliged to take part in the Trojan war in which he was slain by Achilles. At the supplication of Eos, Zeus transferred Memnon from Hades to Olympus.

Thomson's translation of Salverte's "Philosophy of Magic, Prodigies, and Apparent Miracles," published in London in 1846, contains, besides a great number of other curious things, considerable information concerning the speaking statue of Memnon. The upper part of the speaking statue was broken at an unknown period. This accident, however, did not prevent the sounds from still being heard; for it is declared that on the rising of the sun the sounds were heard as before, now appearing to come from the lower part of the monolith. Letronne, in a book known as "La Statue Vocale de Memnon" (The Speaking Statue of Memnon), says the statue was restored during the third century of the Christian Era, masses of gray stone being substituted for the destroyed portions of the single stone from which the statue had been originally hewn.

The Colossi of Thebes were two statues, or effigies, of the same Egyptian king, Amenoph, or Amenhotep, or Amenophis III, a sovereign of the eighteenth dynasty, who reigned about 1500 B. C. The architect who made the statue was of the same name as his royal master, Amenhotep, son of Hapu. Among other inscriptions engraved on a statue of the architect himself are the following words:

"For my lord, the king, was created the monument of sandstone. This did I which seemed best in my own eyes, causing to be made two images of a noble, hard stone in his likeness, in this his great building, which is like unto heaven. . . .

"After this manner made I perfect the king's images, wonderful for their breadth, lofty in their height. The stature whereof made the gate towers to look small. Forty cubits [1] was their measure. In the glorious sandstone mountain wrought I them. On this side and on that, on the east side and on the west. Furthermore, I caused to be built eight ships wherein they were carried up and set in this lofty building. It will last as long as the heaven endureth."

[1] The cubit can be taken as equal to 18.25 inches.

The following description of the appearance of the statue of Memnon was given in a paper read before the Royal Society in London in 1843.

"Each figure represents a colossal male seated on a throne supported on a pedestal. The features of the face have long ago been so hacked as to be indistinguishable. The arms, drawn close to its sides, rest on its stalwart thighs; the hands with their outstretched fingers are turned slightly inward, and rest on the knees. The attitude is that of a giant resting after the fatigue of a successful war. The height of the figure is fifty-one feet excluding the pedestal, or sixty-four feet with the pedestal."

The Egyptians declare that when Cambyses, the Persian, conquered Egypt, he ordered the speaking statue of Memnon to be destroyed, as well as other sacred monuments of Egypt. This fact, however, is questioned by Strabo, the ancient geographer, who declares that the statue was overthrown by an earthquake which destroyed many buildings in Egypt.

It does not appear that the speaking statue made any especial impression on the Egyptians, probably because they knew of other speaking statues. When, however, Egypt was conquered by Cambyses, as well as during later years, it attracted no little attention; and it gradually became the custom of distinguished Greek and Roman travellers, great generals, or rulers, who visited Egypt and heard the statue address the sun, to engrave on it what they had heard. A rivalry appears to have arisen between these distinguished men to outdo one another in what they claim they heard the statue speak; for, when more was so said to one traveller than to another it proved that this traveller was especially favored by the gods. Whether this is true or not, the successive inscriptions are more and more wonderful as the number of distinguished visitors who came to the statue increased.

The fame of the speaking statue being thus spread by its distinguished visitors, naturally caused many of the ancient writers to refer to it. I will quote some of them from explanatory notes added by Thomson to his translation of Salverte's book.

Dionysius, a Roman writer of the Augustian Age, speaks in verse of "The ancient Thebes where the sonorous Memnon hails the rising of Aurora." (The Day or the Morn.)

Strabo writes:

"There were two colossal statues, each composed of a single stone, and standing near one another. One of them remains entire. It is said that the upper part of the other was overturned by an earthquake; and it is also believed that a sound, resembling that produced by a slight blow, proceeds from the base, and from that part of the colossus resting on it. I, myself, in company with Aelius Gallus, and a number of his soldiers, heard it towards the dawn of day. But whether, in reality, it proceeded from the base of the colossus, or was produced by connivance, I cannot decide. In uncertainty of the real cause, it is better to believe anything than to admit that a sound can issue from stones similarly disposed."

The elder Pliny, the Roman historian (born A. D. 23), says: "At Thebes, in the Temple of Serapis, stands the image said to be consecrated to Memnon, which, daily, is heard to emit a sound when the first rays of the sun fall upon it."

Letronne has restored and translated some seventy-two of these inscriptions, engraved on the sides of the statue by its distinguished visitors from which it would seem that the statue does not always employ the same words, nor did it always limit this speech to the exact hour of sunrise. You will be able to understand this better if I quote for you, in brief, some of these inscriptions. No less than six of these inscriptions declare that the statue had spoken twice during the same day. Another declares that, at the time of the visit of the Emperor Adrian, the statue had spoken three times during the same day. This, of course, was alleged to be a special miracle that was granted as an evidence of the favor of the gods to the emperor.

Another inscription declares that the statue actually made an address to Adrian, speaking to him in a very friendly manner.

Still another inscription is as follows:

"Memnon, the son of Tithon and Aurora, up to this date, had merely permitted us to hear his voice; to-day he greeted us as his allies and friends. I caught the meaning of the words as they issued from the stone. They were inspired by nature, the creator of all things."

Accounts vary as regards the character of the sounds uttered by the statue at the dawn of day. Some say that they were musical sounds, not unlike those produced by a lute, or by a copper instrument. Others declare that distinct words were uttered which were entirely understood by the hearer.

And now as to the manner in which the statue was caused to produce these wonderful and distinct sounds. Of course, no one in these times believes that Memnon's speech had anything of a miraculous nature about it. Assuming the accounts as related to be correct, it would certainly appear that some mechanical device was employed for making the statue speak.

Some of the ancient writers in referring to the statue of Memnon appeared to suspect that the sounds were produced by the connivance of the priests. Juvenal says: "The statue of Memnon, the son of Aurora, was so contrived, by a mechanical artifice, that it addressed a greeting both to the sun and to the King, with a voice apparently human. In order to ascertain the source of the apparent miracle, Cambyses caused the statue to be cut in two, after which it continued to salute the sun, but addressed the King no longer."

In later days various explanations have been suggested as to the cause of the sound. One suggestion is that a series of successive musical sounds similar to those employed in the intonations of the Egyptian hymns, as sung by the priests, might have been produced by a simple, mechanical contrivance, by means of which a successive number of blows were struck against a series of tuned metallic plates, similar to those employed in music boxes or harmonicons; and as the ancients were familiar with mechanical contrivances driven by means of compressed air, or by water power, such a device could be readily operated. Another suggestion is made that, since the colossus faced the east and emitted the sounds at the very moment the rays fell on the lips, it might readily be that the so-called miraculous mechanism was put in motion by some physical force the priests had discovered; that, for example, the strong and sudden heat produced by the concentration of the solar rays might be sufficient to expand one or more metallic rods which, by lengthening, might open a supply of compressed air or permit the escape of water from a reservoir, thus operating a device similar to that referred to above.

Still another suggestion was that, if the statue was hollow, the air it contained, being affected by the heat of the sun, might, as it escaped from the statue, be made to produce sounds which the priests might interpret as best suited their interests.

While, of course, it is impossible to say just what contrivances were employed to cause the apparent speaking of the statue, yet I think I can make it clear to you how easy it would be, in the light of our knowledge of physical science to-day, to produce a speaking Memnon who could utterly out-Memnon Memnon himself. You will understand this much better after reading the next chapter.

CHAPTER IX

SPEAKING HEADS AND OTHER ACOUSTIC WONDERS

If the speaking head of Memnon, or the Colossus of Thebes, had been the only statue of its kind in the world we might, perhaps, have been more willing to credit it with supernatural powers, but, when we find it was only one of a great number of similar statues, we are apt to regard its so-called miraculous powers as the result of a fraud practiced by the priests on the credulity of the people.

On a careful study of the writings of the ancients we find descriptions of, or references to, numerous speaking heads, or statues. I will first give you some of these references from Thomson's translation of Salverte's Magic, already referred to.

Pindar, the Greek poet, describes the statues of the Gilded Virgins that adorned the roof of the Temple of Delphi. He says that these statues possessed the power of producing ravishing sounds which apparently came from their lips. It has been suggested that such sounds could readily have been produced by musical instruments concealed in the statues, operated by compressed air. Since the ancients were familiar with hydraulic organs, such devices might readily have been employed to produce the so-called miraculous sounds.

But there is another possible explanation of the manner in which the entrancing sounds from the Gilded Virgins might have been produced. As we have seen, it is easy to transmit both spoken or musical sounds through considerable distances by means of speaking-tubes, and this might readily have been done with the statues on the roof of the Temple of Delphi.

It is said that the so-called ancient magician, Albertus Magnus, constructed many mechanical devices that possessed such strange powers that the common people believed them to be of supernatural origin. Among these were various *automata* or mechanical figures, capable of performing actions, or going through motions, as though they were endowed with life. Among these was the figure of a man, who not only possessed the power of walking, but could talk, answer questions, or solve such problems as might be given to it. It is said that Albertus one day exhibited this automaton to his pupil, Thomas Aquinas. The figure did so many remarkable things that the frightened pupil, believing it to be the work of the devil, broke it into a number of pieces which he threw into the fire.

Wonderful automata have also been constructed during recent times. One of the most celebrated of these, known as the *automaton chess-players*, consisted of a figure of a man seated at a table in front of a chess-board. When his opponent sat down to the table opposite the figure and played a game against his mysterious opponent, the figure would move the pieces on the chess-board with such skill that, I believe in practically all cases, the player, no matter how skilful, was invariably defeated. Napoleon I, who was beaten by the automaton, had Maelzel, the inventor, carefully examine it. Maelzel demonstrated that a dwarf was hidden inside the chest.

But mechanical automata had been produced that operated entirely independently of fraud. I have, myself, seen Faber's Talking Man. This was the figure of a man capable of speaking. The device for speaking consisted of various wind instruments capable of producing a succession of sounds that somewhat resembled human speech. It was, however, at the best, a clumsy device that required for its operation a key-board, not unlike that on a piano, at which the person who operated the mechanism sat, successively striking the proper keys. The result was an odd species of articulate speech not unlike the laborious sounds produced by the deaf when taught to speak.

I need not say to you that, in later days, by means of that wonderful invention of Mr. Edison's, the phonograph, or by that equally wonderful invention, the telephone, first conceived by Philip Riess, a German, and afterwards greatly improved by Bell, an American, articulate speech, of a quality almost equal to that produced by man, is obtained by means of a mechanism almost ridiculously simple in its construction.

But let us come back to the discussion of some of the speaking heads of antiquity. Odin, or Woden, the Scandinavian deity, who occupied in the mythology of the northern countries of Europe a position not unlike that which Zeus, or Jupiter, did among the ancient Greeks, is said to have possessed, among his choicest treasures, a speaking head. Unlike most speaking heads, this one did not consist of an ingeniously devised head made of metal or of wood, but was the head of the great hero, Mirme. It is said that, on the death of Mirme, Odin embalmed the head and, covering it with a thin layer of gold, endowed it with the power of speech. Odin is said to have professed great belief in the oracular powers of this head, for he went to it for advice in all difficult matters.

But, perhaps, one of the most celebrated heads of antiquity was that at Lesbos, or the island of Mitylene, one of the islands of the Grecian Archipelago. This head delivered oracles so frequently fulfilled that this speaking head became famous in all parts of the then known world. It was this oracle that predicted the bloody death of Cyrus, and it is said to have consisted of the embalmed head of Orpheus, who, in Grecian mythology, was said to have been the son of Apollo and the Muse, Calliope. It was Orpheus who is said to have been able to sing so beautifully as not only to charm wild beasts, but to endow inanimate things with the temporary power of life. This speaking head of Lesbos became so celebrated among the ancient Persians that Apollo himself is said to have become jealous of it.

It seems that, at a very early time, the ancients began making speaking heads of the actual heads of the dead, in place of such inanimate things as stone or metal. On the death of a celebrated personage, the head was carefully embalmed, a plate of gold placed under the tongue (for what reason I do not know), and the head then preserved from the air by enclosing it in a thin covering of gold. As you can readily understand, speech, that was believed to come from the lips of one who formerly possessed life, naturally excited much greater wonder on the part of its hearers than a head of wood or metal.

In some places speaking heads, known as the Theraphim, consisting of embalmed heads, were very common, and were claimed to have conversed with the people who consulted them, giving advice on different matters in a similar manner to that of the oracles. For the greater convenience of their operation, these heads were placed against the walls of the temples where they could more readily be operated by the priests hiding on the other side of the wall.

In view of these cases and many others that might be mentioned, I think there can be no reasonable doubt that the speaking statue of Memnon must be regarded as a mechanical fraud. In some manner, which does not seem to have been discovered, the operation of the mechanical device, that was either placed in the statue or was connected with it, appeared to be actually dependent, in some way or other, on the rising of the sun. Ewbank declares that the speaking mechanism was operated by air or vapor dilated by the sun's heat.

Various attempts have been made to show the manner in which the sun's heat might so act on water or other liquid exposed to the sun to raise water. Ewbank thus describes the following device invented by Heron for raising water:

"On the lid of a box or cistern, containing water, is placed a globe, also partly filled with the same fluid. A pipe rises from the cistern to about the center of the globe. Another pipe, through which the water is to be raised, proceeds from near the bottom of the globe and terminates over a vase, or cup, which communicates with the cistern. When the sunbeams fall on the globe, the air within is rarefied and, by its expansion, forces the water through the pipe into the vase, through which it descends again into the cistern. When the sunbeams are withdrawn and the surface of the globe becomes cool, a partial vacuum is formed in the globe, and the pressure of the atmosphere then drives a fresh portion into it from the cistern below, when it is again ready to be acted on by the sun as before. In addition to the air, at first contained in the globe, a quantity of vapor, or low steam, would be evolved by the heat and contribute greatly to the result. The cistern represents an open reservoir which may be at a distance from the globe; and the vase merely exhibits the place of discharge, having no necessary connection with the reservoir."

It was common in ancient temples to provide a dark interior, not unlike the choirs of modern cathedrals, known as the Penetralia, into which the people were not permitted to enter. The doors were opened at the time of sacrifice, so that the people might dimly see the altar and the victim.

It is said that the Penetralia of the temple of Isis at Pompeii contained a small pavilion raised on steps, under which a vault was provided. A similar form of shrine exists at Argos. Originally it had been a temple. An excavation in the rock had been made under the part where the altar was situated, the front and roof of the altar being formed of baked tiles. This altar yet remains; and there still can be seen a secret, subterranean passage that terminates behind the altar. Its entrance is situated at a considerable distance to the right of the person facing the altar, and is contrived so as to leave a small aperture that is readily concealed, and leveled with the surface of the rock. This was just about large enough to permit the entrance of a single person, who could creep along to the back of the altar where, hid by some colossal statue or other screen, he could produce many imposing effects.

It is commonly reported that there were, in many of the palaces of Egypt, labyrinths so arranged that the sudden closing of a door would instantly produce a report not unlike thunder.

Some of the stories told by the ancients concerning the marvels or wonders produced by acoustic principles seem, at first sight, almost incredible. For example: a statement has been made that there exists in certain parts of the world a wonderful stone which, when placed inside a door or entrance to a vault containing treasures, produces terrible noises like thunder as soon as the door was opened.

I need not tell you that no one believes a stone possessing such remarkable properties ever had any actual existence. I can easily see, however, how such a device might be produced by mechanical means. There are chemical substances (which will be described in the chapter on the ignis fatuus, as well as in that on the perpetual lamps) that possess the power of catching fire, or igniting, on contact with air. The ancients were also acquainted with gunpowder. They also appear to have discovered a number of high explosives, among which was, notably, a material known as *fulminating gold*.

Now, it would require but a small spark of fire to ignite an artificial stone consisting of gunpowder or other high explosive. You can understand, therefore, that if, just before such a door was closed, the air of the cavern was filled with some gas containing no air, and a mass of some explosive material was placed near the door, and a small quantity of a chemical that would spontaneously ignite on contact with the air was sprinkled over its surface, as soon as the door was opened and fresh air entered the chamber, fire would be produced, and the stone, exploding, would produce noise like a peal of thunder; or a mass of high explosives might be fired by the friction produced by opening the door.

In a similar manner, it is said that curious caskets had been devised that were employed for the storing of gems, gold, or other articles of great value. These were so arranged that, when the lids were opened by any one not in the secret, a loud noise like that of thunder was produced, evidently by the ignition of a high explosive, possibly by the agency of friction.

After all, when you come to think of the matter, these exploding sentinels were only a kind of *acoustic alarms*, or, as we would call it in these days, *burglar alarms*. In our time, however, we would perform the so-called miracle by means of electricity. I do not doubt but that many of my readers, young as they may be, could devise an electric guardian, or sentinel, to protect the treasures placed in a room, or in a drawer, by means of an electric bell placed almost anywhere to suit convenience, that would sound as soon as an electric contact was made on the opening of the door of the room, the lid of the box, or a drawer in a desk or table.

But there was another way in which the most curious effects were produced, especially where the heads of the dead were employed as oracles; or, still better, where the trouble was saved them of preserving a head which should deliver the supposed advice to the applicant; i. e., where spirits, or ghosts, were assumed to appear and to speak to a person. In such cases the method that was probably employed was a manner of speech known as *ventriloquism*.

I have very little doubt, that most of you have seen an exhibition of ventriloquism. If this has been made by an expert, you probably recall the many odd and laughable results that were obtained by words apparently uttered from different parts of the room, or by different objects in a room, without any person being near them. For example, it would certainly be strange to hear from the bottom of a little empty vase, especially if a vase with clear glass so that you can distinctly look through it, a voice shouting out to you that it wants a drink, or to hear another voice crying out apparently in agony, "Get off of me. Don't you see you are standing on my head?" Or to hear two figures, say of Punch and Judy, calling each other names, and behaving in the general unseemly way in which this distinguished man and woman are believed to spend a large portion of their lives.

I will not attempt to explain to you the manner in which a person, without apparently moving his lips, is capable of speaking or talking in such a manner that the sounds, instead of coming out of his lips, appear to come from any part of the room that he may desire. But this strange power does exist, and, when employed by an expert, produces results that appear almost incredible.

If, in our enlightened age, sensible people are surprised and puzzled by ventriloquism, you can understand how easy it would have been, in the past, when people were much more superstitious than they are now, to excite their wonder, and how natural it would have been for them to regard such results as more than human; that is, supernatural.

Thomson, in his translation of Salverte, tells the following story of the manner in which a ventriloquist employed his strange power:

"One of the most successful of ventriloquists of modern times was M. St. Gille, a grocer, of St. Germain en Laye. He exhibited his art merely as a matter of amusement, but with a degree of skill which appears almost incredible. He had occasion to take shelter from a storm in a convent while the monks were lamenting, over the tomb of a lately deceased brother, the few honours that had been paid to his memory. A voice was suddenly heard to proceed from the roof of the choir bewailing the condition of the deceased in purgatory, and reproving the brotherhood for their want of zeal. The tidings of this supernatural event brought the whole brotherhood into the church. The voice again repeated its lamentations and reproaches, and the whole convent fell upon their faces and vowed to make a reparation of their error. They accordingly chanted in full choir a De Profundis, during the intervals of which the spirit of the departed monk expressed his satisfaction at their pious exercises. The Prior afterwards expressed himself strongly against modern scepticism on the subject of apparitions; and M. Gille had great difficulty in convincing the fraternity that the apparent miracle was a deception.

CHAPTER X

FAHRENHEIT AND THE THERMOMETER—TEMPERATURES OF THE HIGHER REGIONS OF THE ATMOSPHERE

It is well known that the temperature of the atmosphere decreases with the elevation above the general level of the sea. This can be seen by climbing a high, snow-clad mountain in the equatorial regions. Near the base, we find the hot climate of the equator with its characteristic tropical vegetation; above this, the cooler air, and the characteristic vegetation of the temperate zones; then the stunted vegetation of the polar zones; while near the summit the climate is cold as that of the poles, with its eternal snow and ice.

The question frequently arises as to how far this decrease in the temperature of the air continues. Does the atmosphere continually grow colder the higher one rises? If means could be devised for soaring through the entire atmosphere, would the temperature be found to decrease constantly to the upper surface?

Before the invention of the balloon, there was no way of positively answering such questions. But as soon as man was able, by the use of this device, to penetrate the aërial ocean for distances above the tops of the highest mountains, it was natural that one of the first problems he wanted to solve was the temperatures of these hitherto inaccessible regions.

When the first aëronaut reached the higher regions of the atmosphere, he did not need a thermometer to know that the air was cold, especially if he had been foolish enough not to provide himself with warm clothing. While the temperature at the surface from which he ascended might have been uncomfortably hot, yet, as he reached the higher regions, the air grew so cold that he began to suffer severely. The balloon, in its rapid upward flight, carried him successively through air temperatures that corresponded to autumn and winter, and that, too, with a suddenness of change that made such differences all the more painful to bear.

But while there would be no difficulty in the aëronaut's knowing that these differences of temperature existed without the use of a thermometer, no observations he could make based entirely on his feelings would be of any real value from a scientific standpoint. It is true that, in an endeavor to describe these differences of temperature at different elevations, he might speak of them as excessively hot, more than usually hot, hot, warm, cool, cold, very cold, and excessively cold; yet such comparative terms would be of but little use to others, since the same temperatures might easily affect other people differently from the way they affected him.

There is a still more important reason why it would be impossible to make observations concerning the temperatures of the air, or other bodies, without the aid of a thermometer. You may be surprised when I tell you that you cannot always determine by feeling a thing whether it is hot or cold. I imagine I see you smiling as you read this statement, since you probably believe that, if you are sure of anything, you are sure of being able to determine whether a thing is hot or cold by touching it. Therefore, before going further, I will endeavor to show you how wrong you are in this belief.

On a very cold winter day when, perhaps, you have been walking so slowly through the street that you have become thoroughly chilled; or, when you have imprudently gone out of the warm house without an overcoat, you have hastened back to the house saying to yourself, "I did not think it was so cold outside the house." As you hurriedly seek its shelter for protection, you pass into the entry and truly say: "Well, it's nice and warm here, anyhow." And then enter perhaps the dining room, and eat a hearty dinner.

The eating of a dinner, especially to a healthy young person, although a pleasant occupation, is, to some extent, a lengthy one. It will take you at least a half hour, and, if you are wise, and eat slowly, possibly from three-quarters of an hour to an hour.

Now note carefully what happens. I will assume, as is true in every well-regulated house, that the temperature, especially at dinner time, does not change markedly from time to time. The entry, therefore, between the dining room and the front door has the same temperature it had when you passed through it just before dinner, and expressed your satisfaction at its being so warm; but as you again pass through it to reach the stairs leading to the second story you probably exclaim: "How cold this entry is." You can understand from this how useless your feelings are to enable you to determine differences in temperature.

Moreover, the vitality of the human system varies with age. Healthy, vigorous people, such as strong children and healthy adults, are more able to bear exposure to either high or low temperatures than old and feeble people. You may remember cases where a grandfather or grandmother, in feeble health, has to your surprise asked to have the temperature of the sitting room made warmer at times when, to you, its heat was already so high as to be uncomfortable.

I think you will agree with me, then, that it is impossible to rely on one's feelings in making reliable observations of temperature. Since, however, you may still be a little skeptical, I will cite for you another case. Let us consider an ordinary bedroom in summer, when there is no artificial source of heat in the room, some time immediately after the sun has gone down, with yet sufficient light to render the use of a candle, lamp, gas flame, or electric lamp unnecessary. Under such conditions, the temperature of every article in the room is the same. Now, if you attempt to determine the temperatures of the different articles by touching them with your bare hands, or, preferably, with a bare foot, the sole of which is generally much more sensitive to differences of temperature than the palm of the hand, I am sure that your feelings will seem to show that the metal door-knob, or the marble sides of a fireplace, or the tiling in the front of an open grate, or the brass andirons in the grate, are far colder than the carpet on the floor, or the wood on the door-jambs or doors, and are especially colder than the soft wool blanket thrown over the end of the bed.

How can this be explained? The answer is very simple. Substances differ markedly in the rapidity with which they conduct, or carry off heat. When two bodies at different temperatures are brought into contact with each other, the body at the higher temperature gives its heat to the colder body. Now, in the bedroom we have referred to, all the articles are colder than your hand or foot. When, therefore, you bring your hand or foot into contact with such good heat conductors as brass or marble, the heat is drawn away, or conducted from your body so rapidly that a feeling of coldness is produced. When, however, you touch a non-conductor, such as wood, or the carpet, or, best of all, the soft blanket, these bodies, being non-conductors, do not permit the heat to escape from your body into the air as it is constantly endeavoring to do, but causes it to collect, and thus raise the temperature of the portions in contact. A thermometer is therefore necessary for observing differences of temperature.

Mercury is generally employed in the thermometer. When, however, very low temperatures are to be measured, some other liquid must be used, since, when the air is very cold, the thermometer might become useless by the freezing of the mercury. For very low temperatures absolute alcohol is employed. There are several thermometer-scales in common use.

In the Fahrenheit scale, the melting point of ice or the freezing point of water, which are exactly the same, is marked 32° F.; and the boiling point of water is marked 212° F. In the Centigrade thermometer, the melting point of ice is marked zero, or 0° C., and the boiling point, 100° C.; while in the Réaumur scale, in which alcohol is employed, the freezing point of water is marked zero, or 0° R., and the boiling point 80° R. In the Fahrenheit scale the length of the tube between the freezing and the boiling points is divided into 180 equal parts, or degrees, and the degree marks continue above the boiling point and below the freezing point.

The degrees on the Centigrade scale are divided into 100 equal parts between 0° C., the freezing point, and 100° C., the boiling point of water, the name Centigrade being taken from two Latin words meaning 100 steps. In a similar manner, in the Réaumur thermometer the scale is divided into 80° between the freezing and the boiling points.

You will see that the zero of the Fahrenheit thermometer is situated at 32° below the freezing point. You may like to know how Fahrenheit came to fix the freezing point of water at 32° above the zero of the scale. It is an interesting story so I will tell it to you.

Gabriel Daniel Fahrenheit, a German physicist, was born at Dantzig in 1686. It is to this man that the credit is due for the first use of mercury in thermometers in place of spirits of wine. It appears that in 1709, there was a very cold winter at Dantzig, Holland. Now, Fahrenheit, who was an ingenious man, and well up in the knowledge of the physics of his day, discovered that he could always exactly reproduce this temperature by the use of a freezing mixture consisting of ice and salt: that is, the mercury in the thermometer always fell to this point when the bulb of the thermometer was surrounded by this mixture. He concluded, although erroneously, that the temperature of this winter as well as that produced by the freezing mixture of ice and salt was the greatest cold that could possibly exist, or, in other words, the absolute zero of cold. Carefully calculating the amount of mercury contained in the bulb and tube of one of his thermometers and dividing it into equal parts, he found that the increase in its temperature caused by plunging the thermometer into melting ice, amounted to exactly thirty-two of these parts. He, therefore, very properly, according to the information he possessed, called the freezing point 32°, or thirty-two steps or degrees on his thermometer scale above the temperature of the absolute zero; and, calculating that the increase in the volume of the mercury when it was raised to the temperature of the boiling point showed an increase of 212 parts above the zero, he marked the boiling point 212°.

The distance on the thermometer scale between the freezing point and boiling point, is divided into 180° on Fahrenheit, into 100° the Centigrade and into only 80° on the Réaumur instrument. The Centigrade thermometer was invented in 1742 by a Swedish philosopher named Celsius. This scale is generally adopted by scientific men in all parts of the world where the decimal, or metric, system is employed.

Armed with the thermometer, an instrument devoid of any other peculiarity than its ability to expand to a certain extent as its temperature increases, the aëronaut, as well as the explorer of mountain slopes, or other high places of the earth, is able accurately to ascertain the changes that occur in the temperature of the air at different distances above the surface of the earth. Generally speaking, the extent of these changes is as follows: for the first thousand feet, the temperature of the air decreases about 3° F., and, roughly speaking, the same rate of decrease occurs for the next few thousand feet. It would not be possible, however, to calculate in this manner, except in a very general way, what the temperature should be at five, ten, fifteen, twenty miles, etc., above the surface of the earth, for it is not probable that this rate continues uniform. Indeed, actual observations made by aëronauts show that, under certain circumstances, the rate of decrease is much more rapid.

There can be but little doubt as to the cause of this decrease in the temperature of the air. Since the air receives the greater part of its heat indirectly from the heated earth, the further we leave the earth's surface the colder the air becomes. The earth may, roughly speaking, be regarded as a stove which heats the earth's atmosphere. Then, of course, the further we get away from the stove the colder the air becomes.

But there is another stove which heats the air; this is the sun; so that the further we get away from one stove, the nearer we get to the other. Indeed, the sun's rays are very powerful in the upper regions of the air, and if the higher air were only dense, and moist enough, it would become fairly hot; because, as you will see in the chapter on climate, it is the moisture of the air that possesses the power of directly absorbing the heat of the sun's rays as they pass through it. This is, probably, the reason for the warm strata of air which aëronauts so frequently meet in the higher regions of the atmosphere.

When it is desired to measure the varying intensity of the sun's rays, a thermometer, known as the *black bulb thermometer*, is employed. This consists of a mercurial thermometer the bulb of which is coated with lampblack; and both bulb and tube are enclosed in a glass tube from which all the air has been exhausted. When such a thermometer is exposed to the sunshine, the black bulb absorbs the heat, while the enclosing glass tube prevents a rapid loss of heat by contact with the cooler air.

Our exact knowledge of the actual temperature of the higher regions of the atmosphere is limited to the regions that have been reached by the aëronaut. It follows, as a matter of course, that in the extreme upper limits of the atmosphere so far from the surface of the earth, where there is little or no air to be heated, and in which there is probably little or no water vapor whatever, the temperature cannot be far below the absolute zero of temperature; that is, the temperature which would result from the absence of all heat whatever. This temperature, as can be shown, is probably about 491° below the zero of the Fahrenheit scale, or 273° below the zero of the Centigrade scale, or, as temperatures below zero are generally marked, —491° F. or —273° C.

Let us come now to some actual observations of the temperatures of the higher regions as made by aëronauts. During the second ascension of Biot and Gay-Lussac, on the 23d of August, 1804, at Paris, the thermometer was 61° F. at the surface of the earth. They found that the temperature of the higher regions was much greater than it generally is at the same altitude on the side of a mountain. This was probably due to the fact of the large quantity of moisture in the air, which was very near to its dew-point; for they noticed that the decrease in the humidity of the air with elevation above the surface did not go on as rapidly as had been expected. At an elevation of 8,600 feet the thermometer had only fallen to 56° F. The direct rays of the sun, however, were so hot as almost to scorch them.

But during another ascension the same gentlemen found the temperature to decrease regularly from 82° F. at the surface of the earth to 47.3°, at an elevation of 12,125 feet. Above this point the temperature decreased, but reached 53.6° at an elevation of 14,000 feet. The increase of temperature at this point being due, apparently, to warm currents of air. From this point the temperature diminished regularly, with some slight exceptions. At the height of 18,636 feet, the thermometer was 32.9°, or near the freezing point; at 22,912 feet above the general surface of Paris, or 23,040 feet above the level of the sea, it sunk to 14.9°.

Referring to these observations on the temperatures of the upper regions of the air by Biot and Gay-Lussac, Turner, in his extensive work entitled "Astra Castra," remarks as follows:

"After making fair allowances, then, for the operation of deranging causes, the results obtained by Gay-Lussac for the gradation of temperature in the atmosphere, appear, on the whole, to agree very nearly with those derived from the formula which theory, guided by delicate experiments, had before assigned. This gradation is evidently not uniform as some philosophers have assumed, but proceeds with augmented rapidity in the more elevated regions."

During the balloon ascension of Glaisher from Wolverhampton, England, on August 18, 1862, when the enormous height of 29,000 feet and over was reached, the temperature of the air at the earth's surface was 59°. When a height of two miles was reached, the temperature of the air had fallen to the freezing point of water; at the height of three miles to 18° F.; at four miles, it was 8° F.; at five miles, 2° below zero or —2° F.

Above this height the aëronauts experienced difficulty in breathing and were therefore unable accurately to read their instruments; so that it is not certain what temperatures were reached at these great elevations. It would appear, however, that at 29,000 feet the temperature fell to 5° below the zero of the Fahrenheit scale.

CHAPTER XI

CLIMATE

By the climate of a country is meant the condition of its atmosphere as regards heat or cold, moisture or dryness, healthfulness or unhealthfulness.

As you all know, it is much warmer in the Torrid Zone than in the Temperate Zones, and much warmer in the Temperate than in the Polar Zones. This is because the sun's rays fall on the surface in the Torrid Zone much more directly, or vertically, than they do in any other place, and more obliquely, or in a slanting direction, in the Polar Zones than elsewhere.

While the surface of the earth receives a small quantity of heat from the interior, and a little from the stars, yet these quantities are so small that we can, practically, regard all of the earth's surface heat as coming from the sun.

The reason for the gradual decrease in temperature from the equator to the poles is due to the fact that the vertical rays of the sun are much warmer than the oblique rays. The Torrid Zone is the hottest part of the earth, because at one time or another during the year, all parts of its surface receive the vertical rays of the sun.

In Fig. 28, the dark shading represents the earth and the part between the circular lines the atmosphere. The height of the atmosphere has been purposely exaggerated for the sake of clearness. The parallel lines represent the rays of light and heat from the sun.

Equal areas of the sun give off equal quantities of heat. If, therefore, the beams of direct, or nearly vertical, rays between *ae* and *bs*, come from the same area as the beams of oblique rays *cg* and *dh*, they will contain the same quantity of heat. But, while the nearly vertical rays are spread over the area *es*, the oblique rays are spread over the much larger

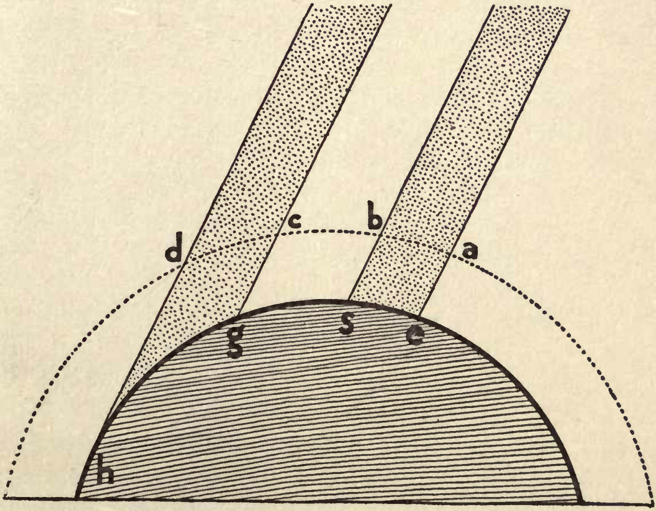


Fig. 28

area *gh*. Therefore the smaller area *es* will become much hotter than the larger area *gh*.

You may be able to understand this better if I use a homely illustration. Instead of spreading equal quantities of heat over unequal areas of the earth, let us imagine we are spreading the same quantity of jam or preserve, say two spoonfuls each, over two slices of bread, one of which is much smaller than the other. I need not tell you that the smaller slice would have the greater intensity of sweetness per unit of area, that is, per bite, than the larger slice. So with the earth. The smaller area *es* will be hotter than the larger area *gh*.

But there is another reason why the vertical rays produce greater heat than the oblique rays. Before reaching the earth's surface, the sun's rays pass through the atmosphere, and during this passage some of the heat is absorbed, so that only a part of the heat reaches the surface. Since, as you can see from the above figure, the oblique rays pass through a thicker layer of air than the vertical rays, they lose more heat, so that a smaller quantity of heat is spread over a larger area of the earth. Hence there is produced a still greater difference of temperature between the temperature of the Equatorial and Polar Zones.

Coming again to the homely illustration of the unequal slices of bread and the equal quantities of jam spread over them, let us suppose that some of the jam on its passage to the bread is spilled, or sampled, before it reaches it. Then we have the least loss for the jam intended for the small slice; hence the difference of sweetness must be still more marked.

But there is another reason for the great difference in temperature between the equatorial and the polar regions of the earth. Both earth and air are constantly losing their heat by radiating it, or throwing it off into space. At night, when the sun is not shining, the temperature decreases, because no heat is received to make up for the loss. The length of time the sun is shining, therefore, will also determine the temperature of different parts of the earth's surface and atmosphere. When the length of the daylight exceeds the length of the darkness, the gain of heat is greater than the loss, and the temperature increases; when, on the contrary, the darkness exceeds the daylight, more heat is lost than is gained, and the temperature decreases.

It is for this reason that the very low temperatures which would be produced in the neighborhood of the poles by the very oblique rays, are prevented, to a great extent, during the short summers, by the fact that the sun's rays continue above the horizon for long periods. For a similar reason, however, the cold in the polar regions is very severe during the long winters, owing to the absence of the sun for long periods of time.

I think you can now understand why the Torrid Zone has almost continuous hot weather, or summers; the Temperate Zones, summer and winter of nearly equal length; and the Polar Zones, short, fairly hot summers followed by long, exceedingly cold winters.

But it is the temperature of the atmosphere, rather than that of the earth over which the atmosphere lies, in which we are most interested. Let us inquire, therefore, briefly, into the way in which the atmosphere receives its heat from the sun.

The sun's rays heat the atmosphere directly, a certain amount of the heat being directly absorbed as it passes through the air.

It was Professor Tyndall who discovered to which particular constituent the atmosphere owes its power of directly absorbing the sun's heat. He showed that the oxygen and the nitrogen of the air were almost completely transparent to the heat that accompanies the sun's rays; that it is the invisible vapor of the atmosphere which stops or directly absorbs much of this heat. He made measurements which proved that the small quantity of vapor generally present in the air possessed a power for absorbing the sun's heat seventy times greater than that of the air through which this vapor is diffused.

You may be surprised to know that there are as great differences in the character of the sun's heat as there are in the character of its light. If a beam of sunlight is passed through a prism, the light is separated into the rainbow group of colored light, known as the *spectrum*, consisting, approximately, of reds, oranges, yellows, greens, blues, indigoes, and violets. These colored rays possess different heating powers. The greatest heating powers are found in the reds of the spectrum and the least in the violets. But a still greater amount of heat is found lower down in the spectrum, below the red; that is to say, the rays of the sun that are unaccompanied by light produce the greatest amount of heat. When the sun's rays heat the earth, and are radiated back into space, they are so changed in their properties that they are almost completely absorbed by the water vapor in the atmosphere as they pass through it.

The sun's rays readily pass through the air to the earth's surface. Only about 28%, or twenty-eight parts in 100, of the vertical rays are absorbed as they pass through the air; 72% reaching the earth's surface. But when the sun's rays heat the earth and the heated earth radiates, or throws its heat back into space, the water vapor in the air acts as an almost impenetrable screen to these rays. The atmosphere, therefore, receives the greater part of its heat indirectly from the heated earth.

You can then see that, as regards its ability to permit the sun's rays to pass through it, and then to prevent them from escaping into space, our atmosphere is not unlike a rat trap, that permits the rat readily to enter, but renders its escape impossible.

If the differences in the heating power of the vertical and oblique rays of the sun were the only causes for the differences of temperature observed on the earth, then the temperature would gradually decrease as we pass from the equator to the poles; but such is not the case. Some parts of the earth are hotter, and some much colder than others, although situated at the same distance from the equator. It is necessary, therefore, to distinguish between what is sometimes called the *astronomical climate*, or the climate produced by the position of the sun, and the *physical climate*, or the climate that exists by reason of certain differences in the land and water areas at different parts of the earth's surface.

The influences that cause the actual or physical climate to differ from the astronomical climate are called *modifiers of climate*. Now let us see what the principal modifiers of climate are, and endeavor to understand the nature of the influences they exert.

If the earth consisted of a uniform surface of land or water, or of land of the same kind and height, then all places at the same distance from the equator would have the same climate; but consisting, as it does, of both land and water areas, and especially of lands possessing different elevations, inclinations, and composition, the actual, or physical, climate must necessarily differ markedly from the astronomical. The reason is as follows. Land heats and cools quickly. It possesses so small a capacity for heat that nearly all the heat it receives from the sun acts to raise its temperature. Moreover, the heat from the sun passes through only a comparatively thin layer of land. For both these reasons, the land after a comparatively short exposure to the sun's rays, takes on a high temperature. In like manner, when land once begins to cool a low temperature is quickly reached.

With water, however, it is different. Water possesses the power of taking in large quantities of heat without becoming very hot, the heat being changed into what is sometimes called latent, or hidden heat. When water begins to cool, it possesses the power of giving out large quantities of heat, and, since most of this heat is that which has been rendered latent, the temperature of the water does not fall very rapidly on cooling.

But, besides this, the sun's heat penetrates a comparatively deep layer of water, and so does not produce as high a temperature as it does in the case of the land, when the heat penetrates only a comparatively thin layer. Moreover, as soon as the water becomes heated, it is pushed out of the way by colder water that takes its place, and this movement, of course, prevents the whole body of water from becoming very hot. Water, therefore, can be exposed either to long heating or long cooling without becoming either very hot or very cold, while land rapidly becomes heated or cooled when it begins to receive or lose heat. For these reasons the land is subject to sudden and great changes of temperature, while water is subject to small and gradual changes of temperature.

The influence of a large body of water on the climate of a place differs so markedly from that of a large body of land in the same latitude, that we distinguish between an *oceanic climate*, or the climate of places situated near the sea, and a *continental climate*, or the climate of places situated at a fairly considerable distance from the sea. An oceanic climate is much less subject to sudden changes of temperature, or, as we say, is more uniform than a continental climate in the same latitude.

It is especially within the tropics that the influence of land areas is most marked. Where there is more land than water in the tropics, a very hot climate results, as, for instance, in Africa, South America, and Australia. In the polar regions, on the contrary, the presence of extended land areas results in a much colder climate than an equal area of water would produce.

Another important modifier of climate is found in the *elevations* of the different land masses. The temperature of the atmosphere decreases rapidly with the elevation above the surface. This decrease is equal to about 3° F. for every 1,000 feet of elevation. The causes of this decrease of temperature with elevation have already been explained.

Climate is also modified by the *inclination of the slopes* of hills or mountains to the rays of the sun. That slope of a hill or mountain which is so inclined to the sun's rays as to receive them more nearly vertically is the hottest. You have probably often heard people in the north temperate zone speaking of a certain field being an early piece of land; that is, one in which the vegetation first appears on the approach of spring. You will generally find such a field on the southern slope of a hill; for this is the slope on whose surface the sun's rays fall more nearly at right angles.

Still another modifier of climate is found in the *position of the mountain ranges* of a country as regards the prevailing winds. An excellent example of this modification is seen in tropical South America, where the huge mountain wall of the Andes stretches from north to south along the entire western coast of the continent. When both the northeast and southeast trade-winds reach the continent, they are chilled by the land and begin to deposit their abundant supplies of moisture. This is especially the case when, forced to climb the high mountain wall of the Andes, they bathe its eastern slopes in copious rains. These mountains are so high, and the trade-winds are so completely deprived of their moisture, that they reach the western slopes of the mountains dry and vaporless. The western slopes are, therefore, barren or desert, while the eastern slopes are traversed by the largest river system in the world, the Amazon.

Another modifier of climate is found in the *nature of the land surface.* Dry desert tracts heat and cool rapidly. The desert of Sahara, intensely heated as it is during the day, is often so cold shortly after the sun goes down that fairly heavy clothing is necessary for comfort. While, on the other hand, land covered with a heavy vegetation, like forests, or land that is wet or marshy, both receives and parts with its heat slowly, so that its climate more closely resembles that of the ocean.

But the air and the waters of the earth are in constant motion, and must, therefore, act as important modifiers of climate; for both the hot winds and the ocean currents move from the equator towards the poles, thus tending to raise the mean temperature of the places they pass through; and, in like manner, the cold winds and currents move towards the equator, thus tending to lower the temperature.

If you look at any map of the world you will see, almost at a glance, the manner in which these modifiers of climate produce marked differences of temperature for places in nearly the same latitude. For example, the coasts of France, Great Britain and Ireland are in nearly the same latitude as those of Quebec and Labrador. Now, as you know, Great

Britain and Ireland are warm and pleasant, while Quebec and Labrador, especially the latter, are cold, and at times of the year almost uninhabitable. So, too, the northern coasts of Norway are in the same latitude as many of the islands of the Arctic Archipelago, off the northern coast of North America. These marked differences of climate are caused largely by the combined effects produced by the wind and the ocean currents, the direction of which makes the western shores of the continent much warmer than the eastern shores.

CHAPTER XII

SOME VERY COLD WINTERS AND VERY HOT SUMMERS

Although the climate of a country remains, as a rule, practically the same year after year, provided the entire year is considered, yet it is by no means true that the temperature or climatic conditions of different parts of different years are always the same.

The total amount of heat given off by the sun does not seem to vary much from year to year. But the manner in which that heat is distributed over different parts of the earth, does vary. Sometimes particular days are much hotter or colder during some years than during others, and sometimes the winters and summers are much more severe than usual.

For example, in portions of Arctic North America, temperatures have occurred during January and February as low as — 75° F., or 75° below the zero of the Fahrenheit scale. As before pointed out, this low temperature is due to the fact that the earth and objects on it have been constantly growing colder by reason of their loss of heat during the long winter night.

It would be difficult for you to form any idea of so low a temperature as 75° below zero. At this temperature the air is so cold that mercury freezes in the bulb of a thermometer. It is, therefore, impossible to use mercurial thermometers in these parts of the world, so the mercury is replaced by nearly pure alcohol. Ordinary alcohol, or alcohol containing a small quantity of water, would not answer for this purpose; for, as Dr. Kane and other well-known Arctic explorers tell us, at these very cold temperatures ordinary whiskey, and wines which contain varying quantities of water, partially solidify, or turn into ice, when left out in the air over night.

Quite amusing changes are produced in ordinary food products by very low temperatures. Dried apples become frozen so hard that they can only be removed from the barrel with difficulty. Sauerkraut is converted into a substance somewhat resembling flakes of mica or isinglass. Lard and butter become so hard that, like sauerkraut, they have to be removed from the barrels or the wooden tubs in which they are kept, by the aid of a cold chisel and sledge hammer.

But it is not only in the uninhabitable regions within the Arctic circle that these very low temperatures occur. Temperatures below zero are common, in winter, in parts of the world where the summer temperatures are fairly high. For example: the Fahrenheit thermometer has registered as low a temperature as nearly 11° below zero in the city of Paris; as low as 22° below zero at both Hamburg and Berlin; as low as 37° below zero at St. Petersburg; as low as 44° below zero at Moscow; and in certain towns of Lapland as low as 58° below zero.

One of the coldest towns in the world is said to be that of Jakutsk, in Siberia, where the thermometer falls as low as 72° below zero in winter.

Kane, the Arctic explorer, experienced temperatures ranging from 60° to 75° below zero.

In order to be able to withstand these low temperatures, the people living in these parts of the world must not only wear unusually warm clothing, but also eat large quantities of fatty foods; for it is the oxidation, or burning, of these foods in the system that keeps our bodies warm.

But, let us now go to the other extreme, and discuss the unusually high temperatures that sometimes occur in the air in different parts of the world. Of course, unusually high temperatures are found generally in the tropics.

For example, we find summer temperatures of 112° F. at

Benares; 113° on the Plain of Peshawur, and 115° at Seringapata.

It is said that during Bonaparte's invasion of Egypt, the temperature of the air in the shade at Suez rose to 126.5° F.

Occasionally, high temperatures are found in the temperate zones; the thermometer frequently reaching 96° F. in the shade at London, 107° at Palmero, 105° at Athens, 102° at Lisbon, 102.5° at Berlin, and 102° at Dresden.

But in desert regions where the air is filled with very fine particles of dust, even higher temperatures are sometimes experienced, so that the air feels almost like that of an oven.

The presence of highly heated dust particles in the air is believed to have been the cause of the frightful loss of life that occurred during the terrible volcanic eruption of Mt. Pelée, in 1902, on Martinique, one of the islands of the Lesser Antilles. During this eruption there suddenly rushed down the side of the mountain a blast of almost white hot air, that, sweeping through the town of St. Pierre, not only destroyed the houses, but nearly wiped out its entire population. This air was literally hotter than the blast of an ordinary furnace, and probably owed its heat entirely to the presence of white hot particles of volcanic dust thrown out of the crater during the eruption.

Having now discussed some very cold and very hot temperatures, I will tell you a few of the noted severe winters and summers that have occurred at different times in different parts of the world.

The winter of 1788–89 is said to have been one of the coldest and longest that has ever been experienced in Europe. In Paris the cold began on the 25th of November, and with the single exception of Christmas Day, continued for nearly two months. Water in the ponds and canals froze to great depths, and wine froze in some of the cellars. The Seine, the Rhone, and Garonne were frozen over. The ice was thick enough on the Rhine to permit loaded wagons to cross. The harbor at Ostend was covered with ice so thick that people crossed it on horseback. The ice formed on the sea at a distance of four leagues outside the fortifications, so that no vessel could enter the harbor. The Thames was frozen even to Gravesend, and during the Christmas holidays, as well as in the early parts of January, its surface was covered with shops.

Of course, so severe a winter caused great suffering, and resulted in the death of many people and animals. In certain parts of France the bread was frozen so hard that it was impossible to cut it until it had been laid before the fire to thaw out. The ice formed so deep in some of the ponds that most of the fish were killed.

It appears that the years 860 and 1234 A. D. were so cold that the Adriatic froze, permitting goods to be transported from Venice to the opposite coast of Dalmatia. During the winter of 1621–1622, a fleet of vessels was ice-bound near Venice.

During the winters of 1305 and 1364 A. D. the air was so cold that the water in the Rhone froze to a depth of fifteen feet.

But it was in 1812–13 that a severe winter occurred which will never be forgotten, not so much because its temperature was so low, but because it occurred when Napoleon made his memorable retreat from Moscow on the 18th of October. The temperature of the air was only about 15° below zero; but, during that awful retreat, no less than 450,000 soldiers perished from cold and hunger.

Flammarion gives the following description of some of the horrors of this awful retreat:

"This winter will ever be remembered for the terrible disasters which attended the retreat of the French army through Russia, after the capture and conflagration of Moscow. The frost set in early all over Europe. The retreat of the army began on the 18th of October; Napoleon left the capital of the Muscovite Empire on the 19th, and the evacuation of the city was complete on the 23d. The army marched towards Smolensk, the snow falling without intermission. The cold became very intense after the 7th of November, and on the 9th the thermometer marked 5° (Fahr.). On the 17th the temperature fell to —15.2° (Fahr.) according to Larry, who had a thermometer suspended from his button-hole. According to Arago, the army corps commanded by Ney escaped from the Russian troops by whom it was surrounded, by crossing the Dnieper, which was frozen over, on the night of the 18th–19th of November. The day before, some Russian troops, with their artillery, had crossed the Dwina upon the ice. The cold diminished, and a thaw began on the 24th, but did not last; so that from the 26th to the 29th, during the fatal passage of the Berezina, the water contained numerous blocks of ice without offering a passage at any point to the troops. The cold soon set in again with fresh intensity; the thermometer fell again to —13° (Fahr.) on the 30th of November; to —22° (Fahr.) on December 3d, and to —35° on the 6th at Molodeczno, the day after Napoleon left Smorgoni, and published the bulletin (No. 29) which informed France of a part of the disasters incurred during this terrible campaign."

One of the earliest and longest winters of the nineteenth century was that of 1829–30. This winter was especially severe in the agricultural countries of southern Europe. The rivers throughout Europe were frozen and when the thaw set in they were flooded, and many men and animals perished in the raging waters. That winter was particularly severe in the higher portions of Switzerland. At Freiburg there were 118 consecutive days on which the temperature was below the zero of the Fahrenheit scale. The Seine was frozen twenty-nine days from the 28th of December to the 26th of January; and, afterwards, from the 5th to the 10th of February; making in all thirty-four days, a period of cold equal to that of the great winter of 1763.

The winter of 1840–41 was also very severe. There were fifty-nine days of freezing weather, twenty-seven of which were consecutive in the city of Paris. It was on the 15th of December of that year that the body of the great Napoleon, on its way from St. Helena to the church of the Invalides, was carried in funeral procession through the Champs Elysées. Great crowds of spectators, as well as an army of soldiers, had assembled along the line of march to see the procession. The weather was then so severe that many of the people died by exposure to the cold; or, having climbed into the trees to get a better view, had their extremities frozen, and, being unable to stand on them, fell to the ground and were killed.

There have been other severe winters, that of 1870–71 being a case in point, but our space will prevent any further references of this character.

Let us now briefly describe some unusually hot summers.

The summer of 1793 was especially noted for the high temperatures that occurred throughout Europe. The heat was first experienced in Paris early in July, and increased rapidly, the hottest days being on the 8th and the 16th of July. On the 9th of July a thunderstorm, accompanied by a severe hailstorm, occurred in a part of France. Hailstones as large as hen's eggs destroyed the crops, while a high wind blew down many of the houses. Another severe hailstorm occurred on the 10th of July. The high temperatures continued throughout the month of July as well as during a part of August. The sky was clear, and the wind, although it blew from the northeast, instead of bringing relief, resembled the wind from a furnace.

The dryness of both air and ground were very marked. The water in the Seine fell below the low water-mark of 1719. The land dried up, hardened, and cracked. It is said that workmen engaged in sinking a well found that the soil was completely dried to a depth of over five feet. There was a total loss of crops as well as of fruit and vines.

Perhaps the hottest summer during the first half of the nineteenth century was that of 1842. In that year an excessive temperature continued in Paris for no less than fifty-one days.

Another hot summer occurred in 1852, when unusually high temperatures were experienced throughout Russia, England, Holland, Belgium, and France. On July 12th the thermometer registered 102.2° at Amsterdam.

Some summers have been remarkable for their great drought as well as their intense heat. During the summer of 1858, a great drought existed throughout nearly all France, as well as through parts of England, Belgium, and Algeria, and great loss was occasioned by the absence of moisture.

But, besides the very cold winters and very hot summers above referred to, it sometimes happens that the temperature of the air rises markedly long before the winter is over, so that the vegetation starts again into life much before the usual time. This occurred during the year 1186. That year was so much out of joint that the apple-trees blossomed in January and bore fruit in February as big as hazel-nuts. The crops were harvested in May, and the vintage was ready in August.

CHAPTER XIII

THE PYTHONESS

No, it was not a serpent; it was a woman; a priestess at the Temple of Apollo, at Delphi, where the great Delphic Oracle was located. The Pythoness, sometimes called the Pythian, took her name from the python, a huge snake, that, according to mythology, haunted the caves on Mt. Parnassus. The python was slain by Apollo, who, for this reason, was afterwards called the Pythian Apollo. It was natural, therefore, to call the priestess, who ministered in his temple, the Pythoness or the Pythian.

The ancients, especially the Greeks, were great believers in oracles. The most celebrated of these were the oracles of Apollo, of which there were about twenty-two. The alleged revelations were made to a person called a medium, who was not unlike the so-called medium of the spiritualists of to-day. This medium generally spoke in unintelligible words which were afterwards interpreted through the agency of the priests.

The most celebrated of the oracles of Apollo was the one at Delphi, which possessed a reputation greater, even, than that of Jupiter at Olympia. At this oracle, and, indeed, at oracles in general, the revelations, or the answers, were always so obscure that it was often impossible to know what the prediction was until the event occurred. This was so especially the case in the oracle at Delphi, that in our time the adjective Delphic is frequently employed to mean ambiguous, uncertain, or double; as, a Delphic answer, meaning an answer that can be construed in different ways according to convenience.

The Delphic Oracle was questioned through the Pythoness. The room where the oracles were delivered was in a grotto, or cave. The Pythoness took her seat on a tripod, placed over an opening in the ground. The applicant was not permitted to put the question until the Pythoness fell under the influence of the gods, or became partially unconscious, or semi-conscious. The words she then spoke were written down. They were generally arranged in verse and great skill was required to interpret them.

As you can see, there is a close resemblance between the methods employed by the Delphic Oracle and those used to-day in clairvoyancy, in which it is claimed that the medium, generally a female, is able, while in a semi-conscious condition known as a trance, to see objects that would otherwise be invisible, and thus be able to answer difficult questions or predict coming events.

At the Delphic Oracle the Pythoness, before she was able to predict the future, had first to be thrown into this mesmeric state. While, of course, it would have been far easier to pretend to be in the condition of a trance, it appears that the priests preferred to bring about this semi-conscious condition by means of gases, which, escaping from the ground, near the priestess, would, when inhaled, throw her into a condition closely resembling a fit, which was assumed to be the mesmeric state. During this time she was supposed to be in consultation with the gods.

Now, while the exact means employed for this purpose are unknown, it is quite possible that the stupefying gas was carbonic acid gas, which as you perhaps know is often given off in large quantities from fissures in the ground in certain parts of the world. If the aperture over which the tripod of the Pythoness was placed actually liberated carbonic acid gas, the Pythoness on breathing this gas would pass into a condition closely resembling that in which she was said to fall; and as it was evident to the people that this condition was clearly beyond her control they would naturally believe that while in her convulsions she was actually seeing things invisible to ordinary sight.

If people to-day should similarly submit themselves to the action of carbonic acid gas, they would be affected in a manner very like that said to have been exhibited by the Pythoness. They would experience dizziness, faintness, and possibly nausea, and, if they continued breathing this poisonous atmosphere too long, these symptons would be followed by convulsions and even by death.

The effects produced on the Pythoness by the exhalations from the fissures under the tripod was attended with such delirium as to necessitate her being, after a time, replaced by others; for there were always several at Delphi assigned to this work. According to Plutarch, three Pythians were employed when the Oracle was visited by many inquirers.

Carbonic acid gas is much denser than ordinary air, its density, as compared with that of air, being 1.529.

FIG. 29. LIBERATING CARBONIC ACID GAS

If a wide-mouthed glass jar containing air only is placed with its mouth upwards on a table, and water is poured into it, the air will be displaced, or driven out of the top of the jar. Since carbonic acid gas is more than half as heavy again as air, it can act like the water in displacing the air in the jar. Fill a large jar with carbonic acid gas. You can easily do this by putting some four or five tablespoonfuls of baking powder in a little water, and placing it in a large jar set on the table with its mouth upwards, as shown in Fig. 29. Then pour in a wine glass full of strong vinegar and an effervescence will take place, bubbles of gas escaping from the liquid, just as they do in a Seidlitz powder, or as you see them escaping from a glass of soda-water. The bubbles consist of carbonic acid gas. As the gas is formed, it collects in the bottom of the jar and drives out the air, just as the water did when poured into a jar filled with air.

Since carbonic acid gas is invisible, you cannot see the height to which it has risen in the jar; that is, the extent to which it has filled the jar. You can determine this, however, in a very simple way. Carbonic acid gas is incapable of supporting combustion. Wrap a piece of wire about the bottom of a candle, so that when you light the candle you can gradually lower it into the jar. Supposing the jar to be full to the level HH, the candle will continue burning at A and B, but as soon as the flame is lowered below the level of the gas as at C, it will be instantly extinguished, and if you are careful in noting the point where the light goes out, you can see how high the jar is filled with carbonic acid gas.

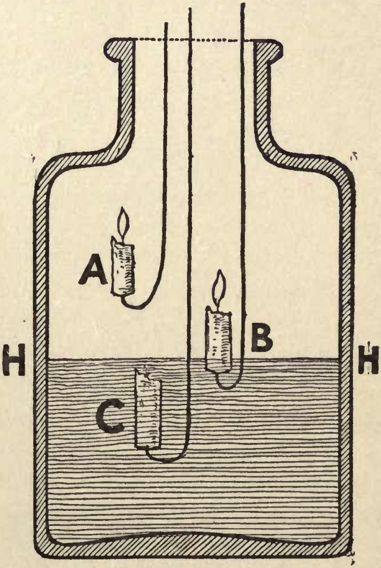


FIG. 30. TESTING FOR PRESENCE OF CARBONIC ACID GAS

In places where carbonic acid gas escapes in large volumes from crevices in the earth, it collects so rapidly in depressions as to drive out the air and so causes the death of all animals. This is especially the case in deep valleys where openings occur through which carbonic acid gas comes from the interior of the earth. Such a valley is shown in cross section in Fig. 31. Animals can no more pass through such valleys from the tops of the hills H, on one side, to the tops of the hills H on the opposite side, than they could descend one of the slopes of a lake basin and reach the opposite slope alive by passing under the waters.

Valleys filled in this way with carbonic acid gas are found in several parts of the earth. The famous "*Valley of the Upas Tree*" in Java is an example. The Upas tree is the

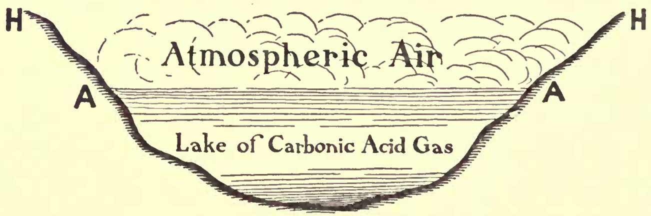


FIG. 31. TYPICAL DEATH VALLEY

name given to a certain tree growing in Java and other tropical countries. It attains a height of more than eighty feet and produces the exceedingly deadly poison, strychnine.

Now, since a Upas tree grows in this valley in Java, it was incorrectly inferred that this tree had so poisoned the air as to make any attempt to reach it fatal to the animals that might approach near enough to breathe its deadly exhalations. A careful examination of the valley, however, made during recent years, shows that the death of the animals is due, not to any poisonous substances given off by the tree, but to large quantities of carbonic acid gas that escape from openings in the ground, collecting in a vast lake of carbonic acid gas filling the valley. When an animal attempts to pass from the highlands on one side of the valley to the other side, it inevitably perishes as soon as it descends below the level of this great gaseous lake. While the lake of carbonic acid gas is constantly diffusing itself through the air, its level is maintained by the constant escape of gas from the ground; for, Java, as you know, is characterized by especial volcanic activity, and the escape of carbonic acid gas from some of its numerous fissures is very rapid.

Another noted instance of a deep valley, filled with a lake of carbonic acid gas that escapes from fissures in the ground, is the famous *Death Gulch* in the northwest corner of Yellowstone Park. "Here," says Dana, "the gas (carbonic acid) rises freely from the waters of Cache Creek, to the destruction of bears and other wild animals. Butterflies and other insects, besides skeletons of bears, elks, squirrels, etc., prove its deadly character."

It is especially in volcanic districts that large quantities of carbonic acid gas escape from fissures in the ground. *The Grotto del Cane* in Italy, near Naples is an example. Here the gas escapes so rapidly that it would soon fill the grotto, were it not for the inclination, or slope, of its floor, down which the heavy gas flows, and thus does not accumulate to a greater depth than a few feet, while above it is the atmosphere. A man can safely walk upright in this grotto, because his head is above the level of the deadly gas. He would quickly die if he were to lie down on the floor of the grotto. A dog, led into the grotto, is soon overcome. I am sorry to say that the Society for the Prevention of Cruelty to Animals has no branch in Naples, or it would stop the cruel exhibitions of the deadly powers of the grotto which are given by dragging a poor animal into the grotto, and then, while nearly choked to death by the gas, dragging it out and reviving it by dashing cold water over it, so as to permit it to be exhibited again and again, until death, less cruel than man, relieves the poor animal of its misery.

Flammarion in his work on the atmosphere gives the following description of the Grotto Del Cane:

"This grotto is situated upon the slopes of a very fertile hill, opposite, and not far from, Lake Agnano. The entrance is closed by a gate of which the keeper retains the key. It has the appearance and shape of a small cell, the walls and vault of which have been rudely cut in the rock. It is about one yard wide, three deep, and one and a half high; and it is difficult to judge from its aspect whether it is of the world of man or of nature. The ground in this cavern is very earthy damp, black, and at times heated. It is, as it were, steeped in a whitish mist, in which can be distinguished small bubbles. This mist is composed of carbonic acid gas, which is colored by a small quantity of aqueous vapor. The stratum of gas is from ten to twenty-five inches high. It represents, therefore, an inclined plane the highest part of which corresponds to the deeper portions of the grotto, and this is a physical consequence of the formation of the ground. The grotto being about on the same level as the opening leading into it, the gas finds its way out at the door, and flows like a rivulet along the hill-path. The stream may be traced for a long distance, and a candle dipped into it at a distance of more than six or seven feet from the grotto is extinguished at once. A dog dies in the grotto in three minutes, a cat in four, a rabbit in seventy-five seconds. A man could not live more than ten minutes if he were to lie down upon this fatal ground. It is said that the Emperor Tiberius had two slaves chained up there, and that they perished at once; and that Peter of Toledo, Viceroy of Naples, shut up in the grotto two men condemned to death, whose end was as rapid."

But the Grotto del Cane is not the only place where carbonic acid gas, escaping from fissures in the earth, collects in such quantities near the surface that it would be dangerous to attempt to sleep on the ground near by. When Boussingault visited the South American volcano of Tunguragua, in 1851, he observed that the horses of the party were apparently unwilling to approach a certain locality near the volcano, throwing up their heads as if they were trying to get them as far as possible from the ground. In this place the ground was covered with dead birds, together with a number of reptiles and hundreds of butterflies. It was simply a region in which large quantities of carbonic acid gas, issuing from openings in the ground, had collected in a nearly pure condition near the surface. One of his Indian guides remarked that he knew no place where one could get so sound a sleep as he could by making his bed on the ground at this place.

It is so common for carbonic acid gas to collect in dangerous quantities in the shafts of some mines, and so cause the death of miners, that we can understand the stories told by the ancients of demons, gnomes, and genii who are placed to keep guard over hidden treasures. These awful watchers were believed to possess the power of slaying all who entered the treasure chambers, either by a single glance of their terrible eyes, or by blasting them by their poisonous breath.

Carbonic acid gas is given off also from openings in the ground in regions that are not at all volcanic. It is always dangerous to descend to the bottom of a deep well, especially a well that has not been used for some time. All wells are apt to contain greater quantities of carbonic acid gas than the surrounding air, owing to the fact that this gas escapes from the ground at the sides and bottom. When the well is frequently used, the air it contains is apt to be stirred up and the carbonic acid gas mechanically removed. When, however, it has not been in use for a long time, the carbonic acid gas collects in such quantities that workmen going down into a well for the purpose of repairing the pump are often killed. Before entering a disused well, one should lower a lighted candle into it. If the candle continues to burn on reaching the bottom of the well, there is no danger from carbonic acid gas. If, however, the candle is extinguished, no attempt should be made to descend until the air is purified. This is readily done by lowering a bundle of lighted hay or straw into the well, when the air currents, caused by the heat, stir up the air and thus remove much of the carbonic acid gas. The well may be safely entered as soon as a lighted candle lowered into it continues to burn.

The air in small, overcrowded rooms is soon deprived of so much of its oxygen, and is so overloaded with carbonic acid gas produced by respiration, that it is impossible to live in it. Such was the case of the famous *Black Hole of Calcutta*, the name given to the military prison of Fort Williams in Calcutta. In June, 1756, Surajah Dowlah shut up 146 prisoners over night in a room having an air capacity of less than 5,900 cubic feet. The room was provided with but two small windows on one side. In about an hour after the people had been shut up they began to show signs of difficulty in breathing, marked thirst, and profuse perspiration. In about three hours and a half most of the people were delirious, and, when the room was opened in the morning, but twenty-three of the prisoners were alive, and they were in an almost dying condition. No less than 123 had been killed by the lack of oxygen. Death here, however, was not entirely due to the presence of carbonic acid gas, or to the absence of oxygen. It was also due, to some extent, to the presence of various gases and vapors that were given off during the respiration of the living, or to gases or vapors escaping from the dead.

A similar instance is found in the case of the ship *Londonderry*. This vessel, leaving Sligo for Liverpool in 1848, encountered a severe storm, during which about 200 steerage passengers were shut over night in a space 18x11x7 feet unprovided with means for ventilation. When the room was opened the next morning, it was found that over seventy of the passengers were dead.

A worse case, even, than either of the above occurred at Austerlitz, where 300 captured soldiers were shut up in a small cellar in which all but forty died in a few hours.

The opinion has been expressed by some that it was not alone the carbonic acid gas escaping from an opening in the ground over which the tripod of the Pythoness was placed that produced the so-called trance; but that there escaped along with it a quantity of *sulphuretted hydrogen.* This may have been so, since this gas is much more poisonous than carbonic acid gas, and would, perhaps, more readily produce the trance condition. Since, however, sulphuretted hydrogen gas possesses, to a marked degree, the disagreeable odor of rotten eggs, it would seem that, had this gas been present, it would have been noticed; and that we should, therefore, find some reference to it in the ancient writings that described the Delphic Oracle.

CHAPTER XIV

WINDS

The comfort and safety of mankind are so dependent on winds, that it is no wonder the ancients, accustomed as they were to attribute all natural phenomena to some supernatural power, should have deified most of the winds. Æolus, the god, who, under the direction of Jupiter, was supposed to rule the winds, had them all shut up in a great cavern on an island in the Mediterranean Sea near Sicily.

Each of the winds had a separate name. The north wind was called Boreas, the son of Astraeus and Eos. Boreas was represented as a heavily bearded, gloomy looking man, covered with warm clothing to indicate the fall of temperature produced by his approach. He was especially worshipped at Athens because, when Xerxes had sailed with the Persian fleet against the Greeks, Boreas had come to their rescue and destroyed the fleet.

The mild west wind was called Zephyros, and was represented as a young man, clothed with a light flowing mantle. Zephyros always carried flowers, since on his approach his warm, humid, pleasant breath caused the flowers at once to burst into bloom.

Of course, no one now believes these ancient poetical ideas. There is nothing supernatural about the winds, for winds are merely masses of air in motion, the cause of the motion being differences of temperature. When in any way the air becomes heated, either by the sun's rays as they pass directly through it, or indirectly from the heated earth, it expands, and, growing lighter, is pushed upwards by the colder heavier air taking its place. This motion is exactly similar to the currents set up in a mass of water that is being heated in a vessel placed over a fire. As the water in contact with the hot bottom of the vessel becomes heated it expands, and, being pushed upwards by the colder heavier water which falls down the sides of the vessel, rises; this interchange between the hot and the cold water going on until all the water in the vessel acquires a uniform boiling temperature. This method of heating a liquid or a gas is known as convection; so sometimes the winds are spoken of as being huge convection currents.

In all convection currents the heated air or water moves towards the colder parts of the air or liquid, and the cold parts towards the heated parts.

Applying this principle to the production of winds it can be said that, although winds blow pretty much in every direction, they generally move as follows:

The heated air in any region of the earth moves towards some colder region, while the cold air moves towards a hotter region; thus, generally speaking, since the earth is warmest at the equator and coolest at the poles, the cold polar air moves usually towards the equator. Since the direction of a current of air is named by the direction from which it blows, the equatorial currents in the Northern Hemisphere are south winds, or blow from the south, while in the Southern Hemisphere they are north winds, or blow from the north. The polar winds, on the other hand, are north winds in the Northern Hemisphere and south winds in the Southern Hemisphere. As these winds move in opposite directions between the poles and the equator, one of them, of course, must blow as an upper current at some distance above the surface of the earth, while the other blows along or near the earth's surface. Generally speaking, it is the hot air from the equator that blows towards the poles as an upper current, while the colder and heavier dense air from the poles flows underneath it along and near the earth's surface.

You will understand, of course, that these directions are only general. The equatorial wind does not always continue blowing directly towards the poles, nor the polar wind directly towards the equator. There are a number of circumstances that tend to change these directions to some extent.

Had our earth no motion on its axis, the direction of these two great air currents, which, for convenience, we will hereafter call the equatorial and the polar currents, would, in the Northern Hemisphere, be due south and north respectively. Since, however, the earth rotates, or turns on its axis from west to east, these currents are turned out of their course to an extent that varies in different parts of the earth. Generally speaking, however, in the Northern Hemisphere the polar currents blow as northeast winds, and the equatorial currents as southwest winds; while in the Southern Hemisphere the polar currents flow as southeast winds, and the equatorial currents as northwest winds.

But the warm, equatorial currents do not continue as upper currents all the way to the poles, nor do the polar currents continue as surface currents all the way to the equator. At certain latitudes, which vary with the seasons of the year, when the equatorial currents have continued as upper currents for a certain distance on their way to the poles, they become chilled, and, falling, take the place of the polar currents that thus become upper currents. This tendency of the polar currents to be lifted into the upper regions of the air is caused by the fact that they gradually become warm as they approach the equator.

I will not attempt, except in an exceedingly brief manner, to trace the different wind zones of the earth, for the matter is a very difficult one. I would say, however, that over the water of the ocean, where local differences of temperature are least apt to disturb the genral direction of the polar and the equatorial currents, the directions of the surface winds are for the most part as follows:

On each side of the equator, generally within the limits of the tropics but varying considerably with the seasons of the year, there is a region in which the polar currents blow as surface winds. In these parts of the world the winds are so constant in their direction that it is generally a matter of surprise when they blow in some other direction. They are known as *trade winds* because of their steadiness and the consequent aid that they afford to commerce. Their direction in the Northern Hemisphere is northeast, and in the Southern Hemisphere, southeast. These two great air streams probably average two miles or over in depth; for, it is only at the higher levels of mountains in the parts of the world over which they blow that they are not found. The trade winds are generally so steady at sea that they may blow for weeks together without the slightest change. Ordinary storms are little known in these parts of the earth, but at times, during certain seasons of the year, terrific revolving storms known as cyclones visit the zones of the trades.

Generally speaking, in the polar zones the polar currents prevail at the surface and are northeast in the Northern and southeast in the Southern Hemisphere.

Between the limits of the trades and the polar winds, or approximately between 40 and 60° of north and south latitude, are regions known as the regions of *prevailing westerly winds*. These are parts of the world where the equatorial currents have fallen to the surface and displaced the polar currents. They are not, like the trade zones, characterized by a wind blowing always in the same direction. On the contrary, a struggle is almost constantly going on between the equatorial and the polar winds as to which shall hug the surface or blow near it. Sometimes one wind and sometimes the other prevails, and inasmuch as the winds may blow from different directions while this change is taking place, this is a part of the world in which one can properly say that a thing is "as changeable as the wind."

There are two parts of the world where for many days together there are no winds, or, as they are called, *zones of* *calms*. The first of these is known as the *zone of equatorial calms*, or the *doldrums*. This zone is situated near the equator, though mainly north of it, its exact position varying with the position of the sun. The zone of equatorial calms is a district where the oppositely blowing trade winds from the northeast and the southeast tend to meet, thus partially checking each other's motion. The calms of this zone are frequently interrupted by light variable winds, squalls, thunderstorms, and cloudy, rainy skies. The zone has a very disagreeable climate which is in marked contrast to that of the trade zones, with its steady, refreshing winds. It is therefore greatly disliked by sailors and indeed by all who pass through it.

The other belts of calms lie on each side of the equator, on the outer margins of the trade winds. That in the Northern Hemisphere is known as the *horse latitudes*. While calms prevail here the weather, unlike that in the equatorial belt, is comparatively fresh and clear. This region has received the name of the horse latitudes from the fact that, during Colonial times, vessels carrying horses from New England to the West Indies, were frequently obliged to throw part of their cargo overboard for lack of fresh water.

The differences in the temperature of the land and water during the day and the night, especially in summer, result in winds called *land breezes* and *sea breezes*, which blow alternately towards and from the sea during the night and the day. These winds are caused as follows. The land heats more rapidly than the water. Therefore, shortly after sunrise when the land becomes heated, an ascending current forms and causes the cold air to blow in from the sea. This is called a sea breeze. The sea breeze generally begins in the morning between nine and eleven o'clock when the land warms.

It is the cool, refreshing sea breezes that make the summer at the seashore so pleasant; for the hotter the day the stronger is the force with which the cool, refreshing sea air blows from the ocean. During the night, when both land and water cool, as the land cools more rapidly than the water, the warmer current ascends from the water, and the cooler air blows out from the land. This breeze is called the land breeze because it comes from the land. It is this colder air blowing over the marshes that surround some of the ocean resorts on the Atlantic seaboard of the United States that brings with it the crowds of mosquitoes which tend to overbalance, to some extent, the pleasures of the seashore during summer. Land and sea breezes are sometimes called *periodical winds,* because they change their direction at regular periods.

There are other periodical winds known as the *monsoons,* a name derived from an Arabic word meaning "season." These are winds that occur on the coasts of the continents in or near the tropics. They differ from land and sea breezes in that they blow in one direction during the warmer half of the year, and in the opposite direction during the cooler half of the year, instead of during the warmer and cooler half of the day. Monsoons are trade winds that are turned out of their course by the overheating of the nearest land during summer.

There are three well known regions of monsoons; namely, in the Indian Ocean, where the N.E. and S.E. trade winds are deflected, or turned out of their course, by the overheating of the continents of Asia, Africa, and Australia; in the Gulf of Guinea, where the northeast trades are deflected by the highly heated continent of Africa; and in the Mexican Gulf and the Caribbean Sea, where the north-east trade winds are deflected by the overheating of the Mississippi Valley.

During the daytime the slopes of high mountains as far as their summits become rapidly heated by the sun and produce an ascending current, which draws the wind up the valley towards the summit. During the night when the slopes of the mountain cool, the cold air flows down the mountain valley from the summit to the base. Both these winds, especially the latter, sometimes assume dangerously high velocities. They are especially noticeable in the mountains of the Sierra Nevada, as well as in the Andes and Himalayas. In the last two ranges they blow up the valleys towards the summits from nine in the morning to an early hour in the evening, and blow down the valleys for the rest of the time.

Besides winds that are caused by differences of temperature produced by the heat of the sun, there are others that are due to the high temperatures occasioned by the eruptions of volcanoes, or to actual whirlings of the air caused by the rapid upward motion of masses of lava shot up through the air during explosive eruptions. During very violent explosive eruptions these winds acquire considerable force.

CHAPTER XV

STORMS, CYCLONES, TORNADOES, WHIRLWINDS, AND WATER-SPOUTS

In meteorology any unusual condition of the atmosphere is called a *storm.* Popularly, a storm is understood to be a very unusual condition of the wind, rainfall, snow, or hail, either with or without lightning and thunder. From a scientific standpoint, however, a storm may exist in the air without any condition unusual of the wind or the moisture of the atmosphere There are such things as heat storms, electric storms, magnetic storms, as well as snowstorms, hailstorms, cyclones, or tornadoes. During most storms, however, the velocity of the wind is greater than usual.

In storms known as *cyclones*, there is an unusual velocity of the wind. The air moves in vast eddies or whirls, revolving around an area called a calm centre, where there is no wind. The pressure of the air as indicated by the barometer is very small immediately over the calm centre, but is high on the sides, especially on that side towards which the storm is moving; for it is characteristic of cyclones that, besides the rotary motion of the wind, the storm advances rapidly over the earth's surface in a curved path.

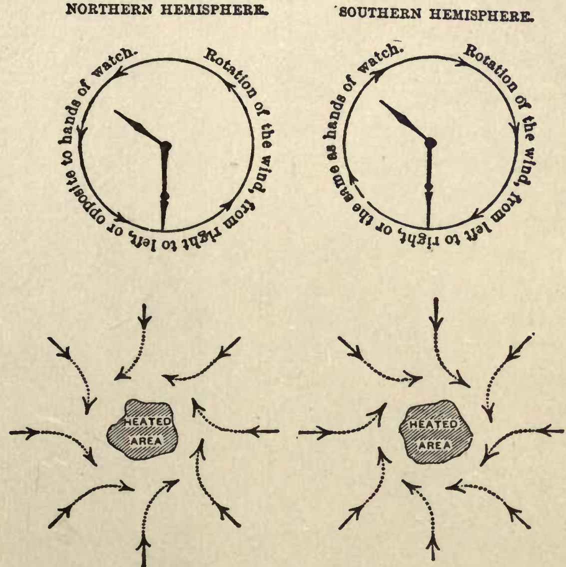
According to Davis, cyclonic storms can be divided into different classes according to the extent of the areas of low barometer over their calm centres. All storms in which these areas are from 500 to 1,000 miles in diameter are known as cyclones. Those with smaller areas of disturbance, say from ten to 100 miles in breadth, are known as *thunderstorms.* These storms, like cyclones, advance broadside across the country and bring with them drenching rain, together with thunder and lightning. Another class of storms of still smaller areas of disturbance, characterized by a violent whirling of the wind with the production of a funnel shaped cloud hanging downward from a larger cloud-mass above, are known as *whirlwinds* or, more correctly, as *tornadoes*.

Cyclones, thunderstorms, and whirlwinds or tornadoes are accompanied by a whirling or rotation of the wind around an area of low barometer, together with a movement of the entire storm over the country.

Though tropical cyclones originate in the tropics only, yet they frequently extend far beyond the tropics into the temperate zones. They are accompanied by immense masses of clouds from which the rain falls in torrents. At the centre of the whirl, where the barometric pressure is lowest, there is often no wind whatever. It is for this reason that this centre is known as the calm centre. Here at times there is neither rain nor clouds, so that the clear blue sky may be seen above. This region is known as the "*eye of the storm*" and is the most dangerous part of the cyclone, for the storm is advancing across the country and the eye of the storm will soon be the fiercest portion of the wind.

Cyclones begin with an ascending current of air over a heated area of low pressure. As the air rushes in from all sides to this area, it is deflected by the rotation of the earth and blows around the heated area in vast whirls, as is shown in Fig. 32. Here two heated areas, one in the Northern Hemisphere and one in the Southern Hemisphere, are represented. Under the influence of the earth's rotation the inblowing winds are caused to move or whirl around the heated area. The direction of rotation of the whirl of wind is always the same in the same hemisphere. In the Northern Hemisphere this direction is from right to left, or opposite to that of the hands of a watch. In the Southern Hemisphere it is from left to right, or in the same direction as the hands of a watch. These directions are indicated in the figure below.

As the wind rushes around the heated area, the centrifugal force, produced by the rotation, lowers the air pressure and causes the calm centre to grow lighter. What especially causes the tremendous force that is generated



From Houston's Physical Geography

FIG. 32. CAUSE OF THE ROTATION OF THE WIND

during these storms, is the heat energy that has been locked up in a latent condition in the water vapor and is set free as the vapor is condensed. The heat thus liberated causes the air to mount higher, and to condense still more of its vapor. In this way the force of the storm rapidly increases.

Since it is to the latent energy of the water vapor, thus liberated, that cyclones owe their great force, they never reach an unusual violence unless the air is nearly saturated with vapor.

The very high velocity acquired by the winds in cyclones is due to the fact that, as the inblowing winds approach the heated areas, they are obliged to blow with greater violence so as to permit the same quantity of air to move over the constantly narrowing path.

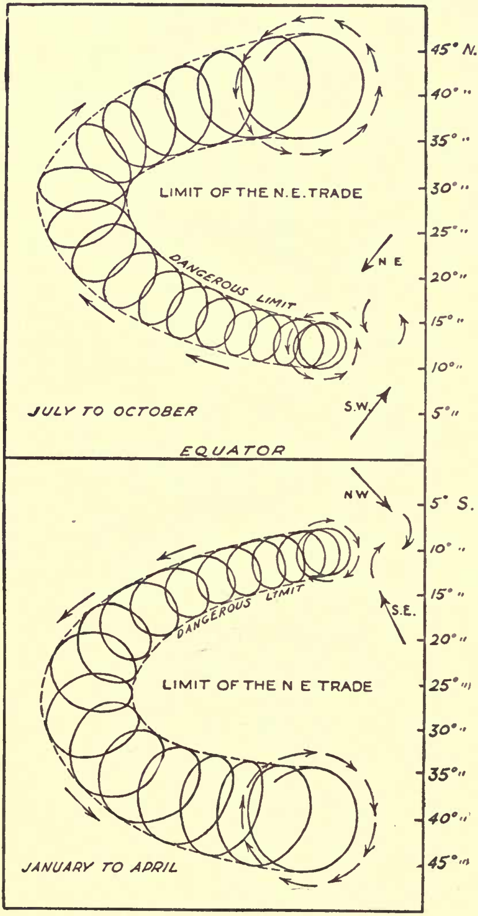


Fig. 33. Parabolic Path of Cyclone

The entire storm area moves onward over the earth's surface in a parabolic path, as represented in Fig. 33. It will be seen that in both hemispheres the movement of the calm centre is towards the west in the tropics, and towards the east in the temperate zones.

Cyclones are most furious near the place from which they start. As they advance and their spiral movements increase in size, the strength of the wind decreases and the quantity of rainfall becomes less. The rotary motion varies from thirty to 100 miles an hour, and the progressive motion from twenty to fifty miles an hour.

There are three well known regions of tropical cyclones: viz., in the West Indies, where they are called *Hurricanes;* in the China Sea, where they are known as *Typhoons;* and in the Indian Ocean, where they are generally called *Cyclones.* In all these districts the storms are apt to occur at the time of the change in direction of the regular winds.

During the passage of a cyclone, waves are produced on the ocean which are not at generally more than a few feet high, but extend over a considerable area. As long as this high water has plenty of room in which to move, no serious results are produced; but when its progress is checked by shallow water, as on approaching the coast of a continent, owing to the immense mass of water propelled, its height becomes terrific and a great amount of damage results.

The coasts of Coromandel in the East Indies have, on several occasions, suffered from these enormous waves. In December, 1789, during a dreadful cyclone, the people on the coast saw three huge waves advancing from the ocean. When these waves reached the coast they swept over the land, causing the death of 20,000 people. Ships, torn from their anchorage, were thrown high and dry on the land, and when the waters had run back they left a surface so covered with mounds of sand and mud that it was impossible to recover the bodies of the dead or regain valuables that had been destroyed.

During the passage of a cyclone in India, in June, 1822, waves produced in a similar manner, rushing up the mouths of the Ganges, drowned about 50,000 of the inhabitants; and during another cyclone that occurred on the 21st of May, 1833, no less than 300 villages were destroyed at the mouth of the Hoogly, and 50,000 people drowned.

Probably the most terrific cyclone of modern times was that known as the "*great hurricane*" of October 10th, 1780. This storm, starting from the Barbadoes, sunk an English fleet anchored at Ste. Lucie, and then ravaged the entire island, blowing down the houses and burying over 6,000 people in the ruins. Then, moving on Martinique, it overtook a French transport fleet, sinking forty ships with 4,000 people, all of whom perished. Further on to the north the islands of San Domingo, St. Vincent, and St. Eustache were devastated, and nearly all the vessels in the track of the cyclone were lost with all on board.

The Great Hurricane was very destructive inland. In Martinique 9,000 people were killed. At St. Pierre, 1,000 people were killed, and not a single house was left standing, for a mass of water from the ocean, twenty-five feet high, rushed over the land. At Port Royal, seven churches, including the cathedral, besides 1,400 houses, were blown down, and many people killed. The loss of life and property was great also elsewhere.

Cyclonic storms, the calm centres of which are more limited than those of cyclones, are called tornadoes. These storms possess both a rotary and a progressive motion. Tornadoes are invariably attended by the production of a funnel-shaped cloud that hangs downward from the bottom of a great mass of thunder clouds, such as is seen in Fig. 34.

FIG. 34. TORNADO

In tornadoes the funnel-shaped mass moves over the surface with a velocity of from twenty to forty miles an hour. This motion is accompanied by a deafening roaring noise. As it passes, everything is destroyed. The tornado may continue for half an hour or an hour. Its destructive path is seldom wider than a quarter of a mile, but may be twenty or more miles in length.

The velocity of the wind in a tornado frequently attains an almost incredible value. The following is condensed from Davis: Houses are torn to pieces and scattered in fragments for hundreds of feet along the path of the storm. Trees torn up by their roots, or actually broken off from their stumps, stripped of their smaller branches, are carried violently through the air, producing great damage when they fall to the earth. People are carried bodily through the air, thrown on the earth and instantly killed. Cattle are frequently impaled by boards or pieces of flying timber. Even heavy plows, logs or chains are carried for many feet through the air. The wind blows so furiously that chickens are stripped of their feathers, and it is even said that nails are driven into boards. There is a case on record in Wisconsin twenty-five years ago of wheat stubble (straw) that had been driven through wooden chips freshly cut from the trees.

When a tornado or whirlwind passes over a water surface it produces a phenomenon known as a *waterspout*. A waterspout consists of a tapering, funnel-shaped cloud, that is first seen as a small pendant, hanging from the under surface of a cloud mass, as in the case of a tornado. As it passes over the water surface the waves are agitated and apparently rise to meet it; so that at last a moving column of water is formed which advances rapidly.

While the spout seems to draw salt water from the sea, yet waterspouts consist for the greater part of fresh water, so that the water they contain must have been condensed from the air. The story is told of a waterspout that, passing over a vessel, so deluged the captain that he was obliged to hold on to some object to prevent being washed overboard. When asked if he had tasted the water, he indignantly inquired how he could help tasting it, since it ran into his nose, eyes, and ears. It was, he said, as fresh as any spring-water he ever tasted.

Waterspouts are most common near the tropics. Although greatly dreaded by ships, I do not remember ever to have read an account of any serious accidents caused by them to large vessels. Of course, it is possible that some of the ships that have sailed out from port and never been heard of again, were destroyed by these formidable looking moving columns.

Waterspouts are not limited to the waters of the oceans. Sometimes similar phenomena, known as *landspouts*, occur, during which enormous funnels or cones reaching downward from the sky move over the surface of the land carrying with them whirling columns of water or of sand. It is probable that some cloud-bursts are due to phenomena of this character.

Waterspouts are frequently attended by electrical phenomena, being accompanied by lightning and thunder as well as by rain or hail. During the passage of these spouts, which are sometimes called *devastating spouts* when they occur over the land, a noise like that produced by carriages rolling over a stony road, or like that of a heavy hailstorm occurs. The smell of ozone is quite common, and sometimes the moving columns emit a phosphorescent light.

CHAPTER XVI

DEVIL WINDS

In some parts of the world there are winds that appear to take such delight in torturing mankind, that they are firmly believed by the uneducated and uncivilized to be under the direct control of the powers of darkness, and are, therefore, called *devil winds*. These winds cause great suffering; some by reason of their very high temperatures, together with either excessive dryness or excessive moisture. Others by reason of their low temperatures and great velocities. Some of them cause such great anguish and loss of life that they appear to be actually poisonous. A few, however, although bringing suffering with them, so far from being poisonous are actually beneficial in the case of certain diseases. All the so-called devil winds are due to unusual differences of temperature that modify the regular winds.

The equatorial deserts are great disturbers of the winds. The winds that blow from their highly heated surfaces reach the adjoining countries laden with fine dust particles, with excessively high temperatures. At the same time the cooler winds blowing over these countries towards the desert bring with them refreshing lower temperatures.

Practically all the countries surrounding a desert have this interchange of winds. The principal hot or devil winds due to the Sahara and its neighboring deserts are the *Harmattan* which blows over the coast of Guinea; the *Simoon,* which blows over Arabia, Nubia, Persia, and Syria; the *Khamsin,* which blows over Egypt; the *Sirocco,* which blows over southern Italy and Sicily; and the *Solano,* which blows over Spain.

The Harmattan is a periodical wind that blows from the desert of Sahara over the coast of Guinea, during the months of December, January, and February. It seldom lasts more than a day or two, although on a few occasions it has been known to continue for two weeks.

The Harmattan is not, generally speaking, a strong wind, but is remarkable for its extreme dryness and heat. While it prevails, small particles of sand, floating in the air, produce a species of dry fog which so obscures the light of the sun, as to render that luminary almost invisible, except during a few hours near noon when it appears as a red disc. The floating dust particles slowly settle on everything, coating trees, ground, and the bodies of animals with a whitish dust. In some of the settlements in this district this fine dust sifts through the doors and windows and quickly coats everything, even in closely shut up places. At the same time the excessive dryness of the air causes the covers of books, the furniture of the rooms, the panels of the doors and windows, and woodwork generally, to dry up and warp, almost as if they had been placed before a hot fire. It produces extremely painful effects on the human body, also. The skin of the hands and face begins to peal; the lips and nose become chapped and sore; and there is a disagreeable itching of the skin.

In view of these unpleasant effects produced by the Harmattan, it is not surprising that a belief should exist that it is poisonous, or, at least, extremely unhealthful. In point of fact, however, it appears that this wind is actually beneficial to those suffering from certain diseases, such as intermittent fever, dysentery, and diseases of the skin generally; for these ailments almost instantly disappear on the approach of the wind.

The stories that are told as to the poisonous character of the Harmattan have probably been purposely circulated by the Arabs for the purpose of dissuading travellers from visiting the desert; for the Arabs are an exclusive people, and desire no intercourse with any of the outside world who are not worshippers of Mahomet.

No dew falls during the prevalence of the Harmattan. Vegetation soon begins to die on the continuance of the wind, and becomes so dry that the natives take advantage of its condition to set fire to the grass and young trees, growing near their roads, so as to destroy the shelter which would otherwise be afforded to their skulking enemies. When thus set on fire, the material burns with such great fierceness, owing to its extreme dryness, as to seriously threaten the lives of travellers. Often the only method of escaping from the rapidly approaching flames, is to set fire to the grass to the leeward, and follow the fire; a practice, by the way, that is common in some of the western prairies of the United States.

Burckhardt, the well-known traveller and writer, gives the following account of a wind of this character that surprised him in the desert.

"When it arose I was alone, mounted upon my dromedary, and far away from any houses or trees. I endeavored to protect my face by covering it with a handkerchief. In the meanwhile, the dromedary, into whose eyes the sand was driving, became alarmed, and began to gallop, causing me to fall off. I remained flat upon the earth, for I could not see ten yards in front of me, and I covered myself with my clothes as well as I could until the wind became less violent. I then went in search of the dromedary, which I found some distance off, lying with his head against a bush to protect it from the sand."

A hot, dry wind similar to the Harmattan sometimes blows over the Kalahari desert, in Southern Africa. Dr. Livingstone, who has frequently experienced the effects of this wind, says that the air is as hot as if it came direct from an oven. The wind seldom lasts longer than a few days, is loaded with a fine sand of a reddish color, and, like the Harmattan, is so intensely dry that it causes all woodwork to shrink. During its prevalence the air is so highly charged with electricity that a bunch of ostrich feathers, held so that the wind will blow directly against them, will, in a few moments, become highly charged, and will repel one another exactly as they would if they were connected with a powerful electric machine.

The *Simoon*, or, as it is frequently called, *Samiel*, is an excessively hot, dry wind that blows over Arabia, Nubia, Persia, and Syria. The wind takes its name Simoon, from an Arabic word meaning poison. There have been so many dreadful stories told about the fatal effects of this hot wind, that a general impression prevails that the wind is actually poisonous, and blasts people with its breath just as would the poisonous exhalations from dangerous reptiles, or highly poisonous chemical substances. But while the Simoon, undoubtedly, frequently causes the death of people exposed to it, it is probable that death is the direct result, not so much of any poisonous substances in the wind, as of the very depressing effects it produces on the human system.

The setting in of the Simoon generally begins with the formation of a black spot in the atmosphere, which appears on a portion of a sky of a general fiery purple color. As the wind begins to blow, the fine particles of sand that are brought suspended in the air from the desert produce a dry fog, the usual accompaniment of the dry desert winds. As these sand particles rapidly increase in number, the sunlight wanes; animals show great alarm; birds fly off for other regions, while the dromedaries endeavor to find shelter from the sand in the bushes. The Arabs, likewise, try to protect themselves against the moving clouds of sand and, wrapping themselves in their coats, lie down with their heads near their bales of merchandise, which they employ as a sort of bulwark against the wind. They are especially careful to shield their water bags from the hot, dry wind, for, during its prevalence, the water is dried up even while in the tightly closed bags, by evaporation from their moistened surface.

There is no wind that renders travelling in the desert so dangerous as the Simoon. It is not at all strange, therefore, that the belief should exist that this is a poisonous wind; for the air is so dry as to rapidly cause the surface of the body to lose its moisture, and thus to produce a horrible thirst, which seems to set fire to the blood, and which, in most cases, the traveller is unable to satisfy. The fine dust carried by the wind is excessively hot, and not only sifts through the clothing, producing great suffering on coming in contact with the bare skin, but also fills the nostrils, eyes, mouth and lungs, so much so in some cases as to cause death by suffocation. For this reason it is necessary to wrap up the mouth in clothing and breathe the air that is sifted through the porous material. But even under these circumstances, enough fine dust passes through the fabrics to cause much pain.

In order to give you some idea of the dangerous character of the Simoon, I will tell you what is said to have happened when Cambyses sent an army of 50,000 men to destroy the Temple of Jupiter Ammon. This temple is situated on an oasis, some twelve days' journey west of Memphis. The oasis is fringed with a belt of palm trees, and was visited by pilgrims from different parts of the country laden with costly gifts. While the army of Cambyses was approaching this temple, a Simoon suddenly sprung up and the entire army it is said perished miserably.

While this account may have been exaggerated, it is probable that the loss of life was very great; for, in later days, entire caravans have been wiped out by the prevalence of an unusual Simoon. In 1805, a caravan consisting of about 2,000 men and 1,800 camels, was completely destroyed and buried in the sand of the desert.

In the deserts in the neighborhood of both Khiva and Bokhara, near a place that is called in the language of the country by a name meaning "The Place Where Men Perish," a variety of Simoon known as the *Tebbad* occurs. The following vivid description of this wind is given by a traveller:

"As we approached the mountain, the Kervanbaschi and his people, pointing out to us a cloud of dust which seemed to advance towards us, told us to dismount without delay. Our poor camels, more experienced than ourselves, had already recognized the approach of the Tebbad (as this wind is called); and, after raising terrible clamor, they fell down upon their knees and stretched out their necks upon the ground, trying to hide their heads in the sand. Behind their bodies, as behind a sheltering entrenchment, we had just time to crouch when the wind passed over us with a hollow murmur, and covered us with a thick coat of sand. The contact with its first grains seemed like a rain of fire. If we had been exposed to the shock of the Tebbad some twenty miles farther on in the depth of the desert, we should undoubtedly have perished. After its passage the atmosphere became more thick and suffocating. Two of our poorest companions, whose provision of water was exhausted, had to be tied down flat upon the camel's back, as they were quite unable to keep their seat. As long as they could articulate a word their parched lips uttered only the monotonous exclamation, 'Water! water! for pity, only a few drops of water!' Alas! their best friends refused to give them the smallest portion of the precious liquid which in the desert is life; and when on the fourth day we arrived at Mederma Bulag, one of these poor wretches was delivered by death from the torture of thirst."

Frequently, when these hot winds pass over the shifting sands of the desert, they raise enormous clouds of sand that threaten to bury the caravans they overtake. Sometimes during these storms a rotary motion occurs, so that huge whirlwinds carry pillars of moving sand over the desert. The general appearance of such a sand whirlwind can be seen in Fig. 35. The movement of sand storms is frequently attended by sounds not unlike the hissing of a serpent, possibly due to the rubbing together of the sand particles under the influence of the strong wind.

The Simoon, or Samiel, receives other names when it blows over different parts of the world. Over parts of Egypt it is known as the *Khamsin*. Like the Simoon, the Khamsin is a hot and dry wind, that is loaded with large quantities of fine sand, and produces great suffering to people exposed to it. The Khamsin wind takes its name from a word meaning fifty, which is applied to the wind because, when it is once established, it generally continues to blow for fifty days, twenty-five of these days being before the time of the spring equinox, and the same number afterwards.

FIG. 35. SAND WHIRLWIND

The *Sirocco* is another hot wind that blows from the desert of Sahara over Italy. Unlike the hot winds mentioned above, however, the Sirocco is laden with moisture which it absorbs while crossing the Mediterranean Sea. It does not, however, lose its high temperature; so that during its prevalence it causes great suffering by the enervating influence it has on the body. When the Sirocco continues for several days at a time, the suffering becomes very great. The air is heavily laden with moisture, but still retains the dust it brings from the desert. The particles of suspended dust it carries permits its temperature to become very high, temperatures of 110° in the shade being common, If you have ever experienced that terrible feeling known as spring fever, which occurs in the early part of the spring, during times of unusual moisture and heat, you may be able to form some idea of the suffering occasioned by the prevalence of the Sirocco. I can assure you, however, that the worst attack of spring fever you have ever had cannot begin to approach in severity the debilitating effect of this hot, moist wind that blows over Italy from the desert.

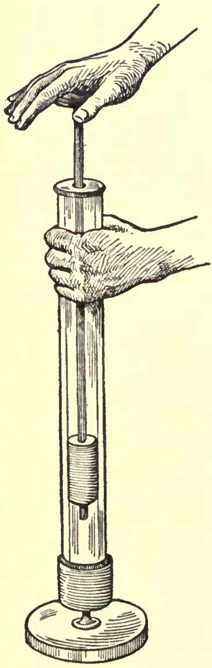


FIG. 36. COMPRESSING PUMP

The *Solano* is a name given to a wind similar to the Sirocco, that blows from the great desert over Spain.

There is a hot southerly wind called the *Foehn*, *Fön*, or *Chinook* that sometimes crosses the Alps and blows down its mountain valleys, which is regarded by some as a continuation of the Sirocco. This wind is probably due to the fact that the hot, dry winds from the desert, blowing as an upper current, are drawn into the valleys by the passage of an area of low barometer, or a cyclonic area, over the country in the neighborhood. As the rare wind from the higher regions rushes down the valley, it is condensed as it falls, owing to the pressure of the air upon it. When air is compressed, its temperature rises. Indeed, it is possible to compress air to such an extent, by the use of the compressing pump shown in Fig. 36, that a bit of tinder or other combustible material can be set on fire. When, therefore, the Foehn is drawn down the mountain valley, the condensation to which it is exposed raises its temperature, so that what was a cold wind upon the mountain top reaches the valley as an unusually warm and dry wind.

This is especially the case in Swiss valleys just before the approach of a cyclonic storm.

Although the Foehn blows with the violence of a hurricane, tears trees up by the roots, and even dislodges rocks, causing them to roll down the mountain slopes, and produces torrents that sweep over the land, yet its arrival is generally gladly welcomed by the people; for this wind is the herald of spring. Its warm air rapidly melts the great masses of ice and snow that have accumulated in the upper mountain valleys; it can do more in a single day to change the appearance of the surface than the sun can in a fortnight. Indeed, it is doubtful whether, in some of the high mountain valleys, there would be any spring at all, or that the grapes could ripen in autumn in some of the plains without the help of this wind.

During the prevalence of the Foehn it is necessary to put out all fires in the houses in the mountain valleys, since a fire started in one of the houses might result in the destruction of the entire village.

Coming now to some of the exceptionally cold winds, we will first describe the *Bora*, a cold, dry, strong wind that blows from the northeast over the coasts of the Adriatic and the Black Seas, sometimes lasting for several days. It takes its name from Boreas, the god of the north wind.

The Bora is greatly dreaded. During its prevalence it blows with a velocity that rivals that of most hurricanes. When it blows in winter over the sea, the spray is carried great distances inland. Clothes wet by this spray are frozen stiff on the body in a few moments, thus causing great suffering. There is also a species of fog produced by small particles of water being carried into the air from the sea by the wind blowing forcibly over the surface. This fog is known as the *Fumarea* or the *Spalmeggio*.

The *Mistral* is a cold wind, corresponding to the Adriatric Bora, that blows in the south of France over the Gulf of Lyons, sometimes even reaching Algiers.

Reference has been made in a previous chapter to the cold breezes that sometimes roll violently from the summit of snow-clad mountains down into the valleys. An hour or more after sunset these winds rush down the mountains with icy blast, at a speed that is sometimes fatal to travellers. Darwin gives the following description of a wind of this character that blew down the Cordillera:

"My guide was passing the Cordillera with a party in the month of May; and while in the central parts a furious gale of wind arose, so that the men could hardly cling on their mules, and stones were flying along the ground. The day was cloudless, and not a speck of snow fell, but the temperature was low. It is probable that the thermometer would not have stood very many degrees below the freezing point; but the effect on their bodies, ill-protected by clothing, must have been in proportion to the rapidity of the current of cold air. My guide's brother tried to return, but he perished, and his body was found two years afterwards, lying by the side of his mule near the road, with the bridle still in his hand. Two other men of the party lost their fingers and toes; and out of 200 mules and thirty cows, only fourteen mules escaped alive. Many years ago, the whole of a party are supposed to have perished from a similar cause, but their bodies to this day have never been discovered. The union of a cloudless sky, low temperature, and a furious gale of wind, must be, I should think, in all parts of the world, an unusual occurrence."

The *Pamperos* is the name given to violent winds from the west and southwest that sweep over the grassy plains, or pampas, of South America. These winds are species of exceedingly violent thunderstorms, and occur in the summer season. They begin like the thunderstorms in the United States. The squall wind brings a tremendous cloud of dust from the dry pampas, and is shortly afterwards followed by a drenching rainstorm with incessant lightning and thunder. The pamperos is greatly dreaded by the vessels in the estuary of the Rio de la Plata.

CHAPTER XVII

THE MOISTURE OF THE ATMOSPHERE

Probably most of you have heard the story of the Prince who had the good fortune to possess a very remarkable cap. When he placed this cap on his head he immediately became invisible. When he wished to be seen again he had only to remove the cap from his head. The Prince, of course, had much fun playing tricks on people, as well as in punishing those who ought to be punished for the mean things they did to others, especially when they thought they could do so safely.

The story of the Invisible Prince, like many other fairy stories, is by no means as absurd as it may appear when first heard. It is not impossible to make a thing invisible and then to cause it to reappear. I do not mean making it invisible by wrapping it up in a piece of black paper, or shutting it up in drawers or closets, or covering it with boards or opaque substances; but to make it disappear right before your eyes while you are carefully watching it, and then to cause it to reappear right in the air before you, as if it were being formed out of nothing. This would surely be a wonder of the atmosphere of a very high kind.

You have no difficulty in seeing water in a glass placed on a table in the sunlight. The tumbler is not cracked nor broken, and will not leak. Therefore, the water cannot run out, and yet, if time enough be given, it will completely disappear, just as if it no longer had an existence. You may look around for it, but it cannot be found on the sides of the tumbler, nor on the table on which it is standing. It cannot be seen in the air; it cannot be seen anywhere.

It is just as if the water, like the Prince, had put on a magic cap and become invisible.

When the Prince became invisible he remained near the people who were vainly looking for him, quietly laughing at them. So, too, in the case of the invisible water, it is near, and I can almost imagine it laughing at your vain endeavors to see it. I am sure, however, I can show you how easy it is to compel it again to become visible, by taking away from it the thing (we will agree to call it a cap) that has enabled it to become invisible.

Since it would take too long a time to watch a tumbler of water until it entirely disappeared, you may save time by pouring the same quantity of water into a large dish; or, still better, by sprinkling it over an extended surface, such as a sheet, and hanging the sheet on a clothes-line where it may be exposed to the air. As you well know, before long the water will entirely disappear from the sheet and become invisible.

I imagine that by this time you understand just what happens to the water when it becomes invisible. You will say, and correctly, that the water disappears because it *dries up*. Yes, the water dries up and disappears in the air; or, more correctly speaking, the water *evaporates*, or changes from a visible liquid to an invisible vapor. For water to become invisible, it is only necessary to convert it into a vapor.

Water is capable of existing in three different states: as a solid or *ice;* as a liquid, or ordinary *water;* and as a *vapor.* Ice or water can readily be seen, while water vapor is invisible.

I need not tell you that in order to change ice into water heat must be applied. In the same way, in order to change water into water vapor an additional amount of heat is necessary.

There is practically always a certain quantity of invisible water vapor in the atmosphere. Water vapor is continually passing into the air from every water surface, or wet or moistened thing on the earth. When the heat of the sun falls on the ocean, or on lakes or rivers, or when the air comes in contact with any wet surface, a portion of the water takes in some of the heat, is changed into vapor, and becomes invisible. This water vapor is lighter than ordinary air, being only about three-fifths as heavy as air; so it rapidly rises. Moreover, by diffusion, it rapidly spreads through the air, and, being caught by the winds, is carried to all parts of the earth. While water vapor is found at practically all elevations in the air, yet about one-half of the vapor by weight is found within a little over a mile above the level of the sea.

If it were possible for the air to hold an indefinite quantity of vapor, and nothing ever occurred to cool or chill it, it would be only a matter of time when all the water on the earth would exist in an invisible condition. Such an atmosphere would be exceedingly unpleasant to live in. It would be what you would probably call sticky, much like the air on certain hot days towards the end of summer or autumn, when everything seems damp, and you perspire very freely after only a little exercise. Fortunately, however, air is capable of holding only a certain quantity of water vapor. Dry air, or air containing no water vapor, will take up water in an invisible state very rapidly; but as it becomes more and more nearly saturated with vapor, its ability to take up additional vapor decreases, until at last it is saturated, or refuses to take up any more. When in this saturated condition, if its temperature be lowered, some of its invisible vapor again becomes visible as water.

There are a number of circumstances upon which the rapidity of evaporation of water depends.

In the first place the evaporation increases with the temperature of the air. This is because hot air can hold a greater quantity of water vapor than cold air.

The rapidity of evaporation also increases rapidly with the extent of surface exposed. Evaporation takes place only at the surface. Therefore, the greater the surface the more rapid the evaporation. When clothes are hung out to dry, they are spread out as much as possible on the line so as to increase the extent of exposed surface.

The relative dryness or moistness of the air also affects the rapidity with which water evaporates. When the air is dry, evaporation goes on much more rapidly than when the air is moist. When the air becomes saturated with water vapor all evaporation ceases.

The rapidity of evaporation is also dependent on the frequency with which the air is renewed. During perfectly calm weather when there is no air stirring, even when the air contains comparatively little moisture, evaporation is retarded by the fact that the air in immediate contact with the wet surface becomes saturated with moisture, and is unable to take up any more until its moisture is slowly diffused through the surrounding air.

The rapidity of evaporation is also affected by the force with which the atmosphere presses on the surface from which the evaporation is taking place. If the air pressure is great, or, in other words, if the barometer is high, vapor is formed much less rapidly than if the barometer is low. In a vacuum, where there is no pressure, all volatile liquids volatilize instantly. As the air pressure increases, the volatilization goes on more slowly.

Having now inquired into the circumstances that aid or retard the evaporation of water, let us endeavor to understand the conditions that favor the reappearance of the water vapor. Since it is the addition of heat to liquid water that renders it invisible, it naturally follows that, in order to cause the vapor to become visible, the heat must be withdrawn or the vapor cooled.

When air is completely saturated, or contains as much water as it is capable of holding in an invisible state, it is said to be at its *dew-point.* Generally speaking, when a mass of air containing water vapor is lowered in temperature or is made colder, it will become relatively moister until the dew-point is reached. If the temperature be lowered below the dew-point, some of the vapor becomes visible as one of the forms of water.

Coming back now to the story of the Invisible Prince, you will understand that when the Prince took off his magic cap he assumed his old form, so that any one who knew him could at once recognize him. Now this is not the case with water. It may be changed into vapor from a lump of ice; from a mass of snow; from the water of an ocean, a lake or a river; or from the dew-drops on vegetation. When it reappears it may appear in a form entirely different from that it originally had.

I should like to explain fully the different ways in which the air may be chilled so that its invisible vapor may become visible in one form or another; but, since the peculiarities of the different forms of water will be fully described in the "Wonder Book of Water," I will now only very briefly describe them.

When only a thin film of air is cooled by contact with the surfaces of cold bodies, it deposits its vapor as *dew;* but when a mass of air is cooled, its vapor is deposited as *mists, fogs, clouds, rain, sleet, hail,* or *snow,* according to the extent of its cooling as well as the manner in which the cooling has been brought about.

Dew is the name given to the drops of water that are deposited, during the warm days of summer and autumn when the air is loaded with moisture, on the surfaces of the cold bodies with which it comes in contact. Nearly all bodies on the earth lose their heat much more rapidly than the air. Consequently, as soon as the sun sets, they grow so cold that the air which comes in contact with their surfaces is lowered below the dew-point, and deposits its invisible vapor in the form of dewdrops.

As you all know, the outside of a dry glass tumbler when filled with ice water on a warm, damp day, will soon become covered with small drops of water, which come entirely from the thin layer of air that is chilled by contact with the cold sides of the tumbler.

Since some objects cool more rapidly than others the quantity of dew that collects on different kinds of bodies will vary. Plants, for example, receive more dew than the bare, smooth surfaces of rocks or other bodies. Any circumstances, therefore, that permit bodies to lose their heat rapidly will result in an increase in the quantity of dew they receive. It is for this reason that more dew is deposited during a clear night, than during a cloudy night; since the clouds, acting as blankets to the earth, prevent objects from rapidly cooling by flinging back the heat by reflection.

More dew is deposited on a calm night when there is but little wind, than during a windy night; since, unless the moist air remains long enough in contact with the chilled object to grow cold, it cannot deposit its moisture. Moreover, the constant changing of the air prevents the object from growing very cold. A slight breeze, however, favors a deposit of dew, since, after permitting the moist air to deposit all its water vapor, it moves away and permits more moist air to come in contact with the cold object.

What is called *frost*, or *hoarfrost*, is produced when objects lose so much of their heat that they become colder than 32° F., so that the drops of water are frozen as they collect.

When a large mass of moist air is chilled below its dew-point, the first effect produced is that its moisture collects in exceedingly minute drops, which decrease the transparency of the air and produce what are called *mists*, or *fogs*, when near the earth's surface, and *clouds* when above the earth's surface.

Some time ago it was believed that the minute drops in mists, fogs, or clouds, consisted not of drops of water, but of minute hollow *bubbles* or *vesicles* filled with air; and that mists, fogs, or clouds ascended when the air expanded on growing warmer, thus increasing the size of the bubbles. This constitution was thought to be necessary in order to make it possible for a substance like water, which is more than 800 times heavier than air, to remain suspended in the atmosphere for the length of time that fogs and clouds are known to remain. It is now understood, however, that these drops of water are so minute, that the resistance of the air prevents them from readily settling. They are, indeed, very much smaller than the dust particles that are so readily blown about by the wind; although the substances of which most of the dust particles consist are relatively much heavier than water.

Fogs, mists, and clouds are produced when a mass of air is cooled below the temperature of its dew-point in any manner, as by masses of warm, moist, and cold air being thoroughly mixed together. This is, probably, to a great extent, the cause of the dense fogs so common off the fishing banks of Newfoundland.

The particles of water in clouds are constantly settling. Moreover, they are easily tossed about by the winds. Although clouds assume a great variety of forms, they can readily be classified under four primary, and three secondary forms.

The primary form of clouds are the *cirrus*, the *cumulus*, the *stratus*, and the *nimbus*.

The *cirrus cloud* takes its name from its resemblance to a curl, or lock of hair. It is composed of feathery, fleecy masses of cloud particles that are deposited in the higher regions of the atmosphere. Cirrus clouds are so far above the earth's surface that their particles are generally in the condition of ice crystals. It is largely in cirrus clouds that those circular bands, or rings of light called *haloes*, appear around the sun or moon. The cirrus clouds are sometimes called *mare's tails* or *cat's tails.* Their general appearance is shown in Fig. 37.

The *cumulus clouds* consist, as shown in Fig. 37, of dense masses of cloud particles that collect in the lower regions

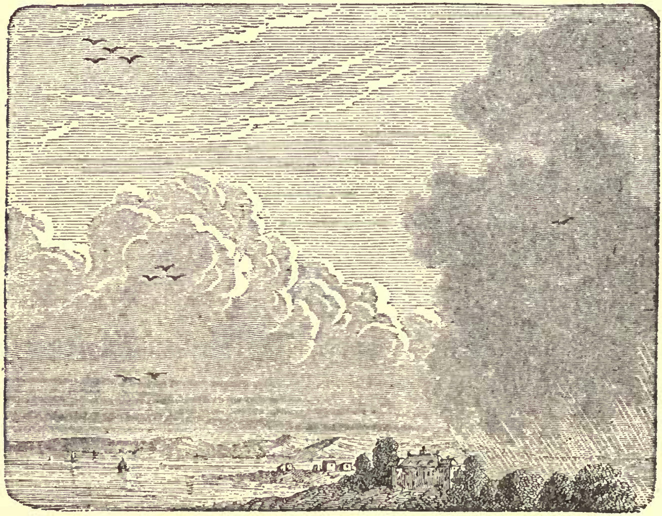


FIG. 37. PRIMARY FORMS OF CLOUDS
One bird—*Nimbus* Three birds—*Cumulus*
Two birds—*Stratus* Four birds—*Cirrus*

of the atmosphere where the amount of water vapor is greatest. They take their name cumulus, or heap clouds, from their rounded tops and sides and flat bases. They are produced by ascending air currents that carry the warm, moist air to the higher regions, where it is chilled by the cold of elevation and expansion. These clouds occur during the hottest parts of the day, and are seldom at a greater distance above the surfacce than two miles.

The *stratus cloud,* as shown in Fig. 37, occurs in the form of horizontal bands, or layers, and is therefore frequently called the *layer cloud.* Stratus clouds are due to the gradual settling of other clouds. For this reason they are common in the early morning and evening when the ascending currents of air are weak. The stratus is the lowest of all forms of clouds. It may become a fog by falling to the surface of the earth.

The *nimbus*, or *storm cloud*, as shown in Fig. 37, is the name given to any cloud from which rain may be falling.

The secondary forms of clouds are the *cirro-stratus*, the *cirro-cumulus*, and the *cumulo-stratus*. As the names indicate, the cirro-stratus and the cirro-cumulus clouds are modifications of the cirrus clouds, while the cumulo-stratus cloud is a modification of the cumulus cloud.

FIG. 38. SECONDARY FORMS OF CLOUDS
One bird—*Cirro-Cumulus*
Two birds—*Cirro-Stratus*
Three birds—*Cumulo-Stratus*

The *cirro-cumulus*, as shown in Fig. 38, is the name given to cirrus clouds when arranged in little rounded masses like small cumuli clouds. Cirro-cumulus clouds are sometimes called "*wool sacks*," and indicate dry weather.

The *cirro-stratus cloud*, as shown in Fig. 38, consists of cirrus clouds that have settled in bands or layers. Since these bands are not continuous, but are arranged in blotches or bars, they give to the sky the appearance of a mackerel's back. Such a sky is frequently known to sailors and others as a *mackerel sky.* It generally indicates coming rain.

In the *cirro-cumulus cloud,* as shown in Fig. 38, there is a mountain-like mass of cumulus clouds heaped together. The top of such clouds resembles the cumulus clouds, while the base partakes of the nature of a stratus cloud.

When, by the continued condensation of the water vapor, the number and size of the water particles in a cloud increase beyond a certain extent, they finally fall to the surface as *rain.* In order to produce rain, the same conditions are necessary as to produce clouds, except that the temperature of a large mass of air must be lowered further below its dew-point than in the case of clouds. This can be done in a variety of ways.

A warm moisture-laden air may change its latitude by blowing towards the poles. When, for example, the warm moist air from the equator blows towards the poles, it deposits its moisture as rain in different parts of its route, by reason of the chilling which takes place as it gets nearer and nearer the poles.

Or, a warm moisture-laden air may, by means of an ascending current, carry the moisture of the lower strata into the higher regions, and there, chilled by the cold of elevation, together with the expansion of air and vapor under decrease of pressure, deposit its moisture as rain. It is principally in this manner that the rains of the Tropical Zones are produced.

Or, a warm moisture-laden air may blow against a high mountain, when, being forced to ascend, it is chilled by contact with the cold upper slopes, and produces rain.

While dense clouds, and probably fine drizzling rains, may be produced by the mingling of masses of moist warm and cold air, the rainfall so brought about can never be very heavy; since, while the warmer air is cooled by mixing with the cold air, the cold air is warmed and its capacity for moisture is thereby increased.

The distribution of rain is dependent on the direction of the winds. Since the equatorial air currents blow generally towards the poles, they are especially rain producing winds; for, as they blow towards the poles, they grow colder and deposit their moisture. The polar currents, however, become warmer as they approach the equator, their capacity for moisture is thus increased, and they take, rather than give moisture. They are, therefore, drought producing winds.

There is a marked exception to this general statement. The polar winds may reach the zones of the trades, after having crossed an ocean. They thus become loaded with moisture, and may cause heavy rains when chilled by contact with the coasts of a continent, or the slopes of high mountains.

The rainfall is so dependent on the character and direction of the winds, that each wind-zone possesses a characteristic rainfall.

As regards its quantity, the amount of rain decreases as we pass from the equator to the poles. More rain falls in the tropics than in the Temperate Zones, and more in the Temperate Zones than in the Polar Zones. More rain falls on the coasts of continents and islands than in the interior, especially on the coasts that receive the prevailing winds.

Deserts are caused entirely by the absence of water. A section of country may possess excellent soil and an abundance of the sun's light and heat; but unless it has a proper rainfall it will be hopelessly sterile or desert. The quantity of rain that falls on a country, therefore, is a matter of the greatest importance, since it determines the character of its vegetation and animal life, as well as that of its people. There are large desert regions on both the Eastern and the Western Continents, those of the Eastern Continent being much more extensive than those of the Western.

Sleet consists of raindrops that are frozen while they fall. When the invisible moisture is frozen while it is condensing, instead of collecting in minute drops, it crystallizes and appears as *snowflakes* or *snow*. Snow crystals assume very beautiful forms. They consist of star-shaped collections of minute crystals. These crystals, however, only form in the absence of a strong wind.

Hail occurs when considerable differences of temperature exist between the higher and lower strata of air and the moisture is rapidly condensed. It is especially apt to occur in summer towards the close of an unusually warm day and during a thunderstorm. Hailstones consist of alternate layers of ice and snow, and are now generally believed to be caused by the whirling or rotation of the air around a horizontal axis, by means of which raindrops are carried through a cold snowcloud where they are both frozen and coated with a layer of snow. The successive coatings of ice and snow are due to the hailstones being carried through rain and snow clouds in turn, until they fall to the earth by reason of their increase in weight.

As a rule, hail falls during a violent thunderstorm. It falls in a narrow path or streak, while the rain covers a much wider area. This narrow streak marks the course of the vortex of the storm, within which the air is highly rarefied. Intense cold is thereby produced, and the moisture in the air is almost instantly frozen, while everything is whirling with great rapidity. Nearly every condition of the atmosphere may be passed through by the forming hailstones, whirling at one moment, among the snowflakes in the next moment and then again whirling in the frigid vortex.

Mr. E. Alexander Scott, of Philadelphia, gives the following description of one of the most remarkable hailstorms on record, which occurred in Philadelphia in the summer of 1870. This storm was noted, not only for its severity, but also for its long duration, and for the restricted area on which the hail fell.

It occurred on a Sunday at noon. The heavens darkened rapidly, as in the formation of a thunderstorm. The sky, however, presented a most unusual spectacle. Instead of the snowcloud rising from one quarter of the heavens, two portentous disturbances approached each other rapidly from opposite quarters, the one from the northeast and the other from the southwest. They advanced like great armies in battle array, huge masses of clouds tumbling over each other like the smoke of a battery of field guns.

Their advance lines were parallel and nearly straight. No rain was falling, and very little fell during the storm. When the contending hosts met, darkness, like night, overshadowed the city. The first scattering hailstones that fell struck the roofs of the houses with such a resounding thud that everybody ran to shut the window-blinds; but none was quick enough to prevent the destruction of glass that followed. For many weeks it was not possible to find enough glass in the country to repair the damage.

The stones were all large, a considerable proportion being the size of black walnuts. They lay piled up against the walls of the houses on the east and south sides of the streets, in some places eighteen inches deep.

The most remarkable feature of the storm was that the hail fell only on a streak about three-quarters of a mile wide, running from southwest to northeast in a straight line; no hail falling in other parts of the city, although it continued to fall for nearly twenty-five minutes. It required hours of hard work to clear the sidewalks.

One of the best evidences of its severity is shown by the fact that the hospitals were filled with persons who came, or were brought there, to have their wounds dressed; many with broken fingers, and multitudes with gashed faces and scalps. Horses generally were badly cut, and many runaways resulted; and in one case a runaway hearse tipped over and deposited its burden in the gutter.

This storm was accompanied by the electrical characteristics usual in thunderstorms, but they were not of an extraordinary character. The storm rather resembled a tornado, or whirling storm, the vortex of which, however, was not low enough to envelope the buildings in its destructive folds.

CHAPTER XVIII

"OLD PROBABILITIES"

"Old Probabilities" was the name given to the Chief of the United States Weather Bureau when the Department was first established by Congress. This name was originally given as a matter of pleasantry, for the predictions all began with: "It is probable;" and it was also believed that weather predictions, even when undertaken by the United States Government, could only be regarded as the more or less shrewd guesses made by the so-called weather prophets. General Myer, who organized the Weather Bureau, was much annoyed by the name, and changed the form to read: "The indications are," etc. The name, "Old Probabilities," though sometimes still given to the Chief of the Weather Bureau, is not employed as much now as it was formerly.

From the earliest times there has been a desire on the part of all kinds of people to know just what the weather will be during the next few hours, or the next day. This is natural, since our comfort is often greatly affected by marked changes in the weather. When it does not rain for long periods of time, the droughts may cause great loss to the wheat or other crops. On the other hand, if the rains are excessive, the lowlands of all large rivers may be visited by great floods, like those that, during the spring of 1897, overflowed the lower Mississippi Valley and, covering an area of some 13,000 square miles, caused a total loss in live stock and crops to a value exceeding $12,000,000. A violent storm at sea may cause even greater losses in vessels and lives. The prevalence of a hot, dry wind may blight the crops in many entire States; while the unusual occurrence of frost in countries like Florida, may cause great money loss by completely ruining the orange crop.

It is impossible for man to prevent these sudden changes in the weather, but, were he able to foresee exactly when such changes were coming, he might take such steps as would either entirely avoid, or at least greatly lessen the damage.

Efforts have been made to predict coming changes in the weather, by observing either the actions of certain animals, or certain appearances of the sun or moon, as well as in many other ways. Such predictions, however, are generally unreliable.

It certainly should be possible to predict coming weather changes. The movements of the wind, or of heated or cold air, the production of a storm, the falling of rain or snow, the coming of frost or of a hot wave, are all natural phenomena that are produced by definite causes. If one knew all of the causes and the exact order in which they acted, he ought to be able correctly to predict coming weather changes. Take the case of a rainstorm. If one knew that the air over a certain section of the country was hot and loaded with moisture, and was certain that changes were coming that would chill the air below its dew-point, he would be as safe in predicting a fall of rain as he would be the falling of an unsupported body to the earth. The difficulty is, however, that so many things might occur to prevent the air from being chilled; or, the moist air may be replaced by hot, dry air, so that, instead of the predicted rainstorm, there might be an unusually dry spell. Another difficulty arises by reason of changes occurring in some distant part of the earth, of which the weather prophet has no knowledge. If he could be in a thousand places at the same time, he might be better able to acquire reputation as a weather prophet.

The telegraph and telephone, and especially wireless telegraphy, enable the weather prophet to acquaint himself with actual weather conditions that exist at any time over all the world. And since the invention of instruments like the barometer, the thermometer, the anemometer, the hygrometer, the pluviometer, etc., enable us readily to determine differences of atmospheric pressure, temperature of the air, wind pressure, and velocity, and the moisture of the atmosphere, the possibility of weather prediction is far less hopeless than might at first appear.

During all the years when scientific men were groping, as it were, in search of means for making intelligent guesses at the weather, a discovery was made that wonderfully simplified weather prediction. I allude to that made by Benjamin Franklin in the city of Philadelphia, about 1747. An eclipse of the moon was to be visible at Philadelphia on a certain Friday night, at nine o'clock. Franklin, who was a natural philosopher of no mean attainments, made preparations for observing this eclipse. Unfortunately, on that night a heavy storm approached Philadelphia from the northeast, continuing all that night and all the next day. Franklin was unable to see the eclipse and make any observations. To his great astonishment, the first newspaper that reached him from Boston after the night of the eclipse, stated that the eclipse had been seen in the city of Boston, the weather being particularly favorable and the sky quite clear of clouds.

Franklin was unable to understand how this could be possible; for Boston lies northeast of Philadelphia, and he had particularly noticed that this storm reached Philadelphia from the northeast and therefore must have passed over Boston. Writing to his brother in Boston for particulars as to the weather, he learned that the storm did not reach Boston for at least an hour after the eclipse was over.

Franklin studied this matter carefully, and finally made the discovery that all the great northeast storms of the United States start somewhere in the southwest, and move in a general northeast path across the country.

In a letter dated Philadelphia, July 16th, 1747, to the Rev. Jared Elliot, Franklin says:

"We have frequently, along this North American coast, storms from the northeast, which blow violently sometimes three or four days. Of these I have had a very singular opinion some years; viz., that, though the course of the wind is from northeast to southwest; yet the course of the storm is from southwest to northeast; that is, the air is in violent motion in Virginia before it moves in Connecticut, and in Connecticut, before it moves at Cape Sable, etc."

This discovery afforded a great help for predictions of coming changes in the weather. If the northeasters and other great storms of the United States move regularly across the country, from an area of low barometer in the southwest to the northeast, it would be easy to telegraph the coming of the storm to all places lying in front of it, and so predict, almost to a certainty, when the storm should reach different parts of its route. The only elements of uncertainty are the exact path the storm will take, and the speed with which it will move from place to place. Since, however, the paths taken by previous storms are well known, it is not difficult to predict the probable path.

The movements of the northeast storms across the United States have been carefully studied since Franklin's time. It is now known that all our great northeast storms are attended by a whirling of the wind around a calm centre, and that they are, in fact, a species of cyclone; that they all start in an area of low barometer somewhere between Minnesota and Texas; that the atmospheric pressure is low over these calm centres and high on its front and rear; that the calm centres, or areas of low barometer, generally move to the northeast and are elliptical in shape; that all northeasters begin by winds blowing towards the area of low barometer, and that, in the Northern Hemisphere, the whirling of the wind around the area of low barometer is in the opposite direction to that of the hands of a watch, or from the right to the left; and, finally, that these storms begin with the wind blowing from the northeast, and end with the wind blowing from the southwest.

The United States Weather Bureau was established by an act of Congress passed February, 1870, authorizing the Secretary of War to establish stations in different parts of the country where observations could be made with the barometer, thermometer, hygrometer, anemometer, and pluviometer. These stations were all connected with one another and with a central office at Washington by telegraph lines. The observations with the different instruments were made simultaneously all over the country twice every day, and telegraphic despatches were sent as to the pressure, temperature, amount of moisture in the air, direction and velocity of the wind, amount of rainfall, and condition of the sky as to the presence of, or freedom from clouds.

When these despatches were received at the Central Office at Washington, a series of charts or maps called graphic charts were prepared. Suppose, for example, there were placed on the walls of one of the rooms a number of separate maps of the United States with small nails driven into the wall through the maps at each of the stations: one map for barometric pressure, one for the temperature of the atmosphere, one for the quantity of moisture in the air, one for cloudiness of the sky, indicating whether it was raining or not, and so on. Now, suppose that as fast as the despatches were received an assistant placed on one nail after another a little circular disc provided with a hole in the middle for supporting it on the pin. In this way each map is at last filled with the appropriate discs, the map representing barometric pressure having only the heights of the barometer marked on it, that representing temperature of the air having only temperatures marked on it, and so on for each of the features observed.

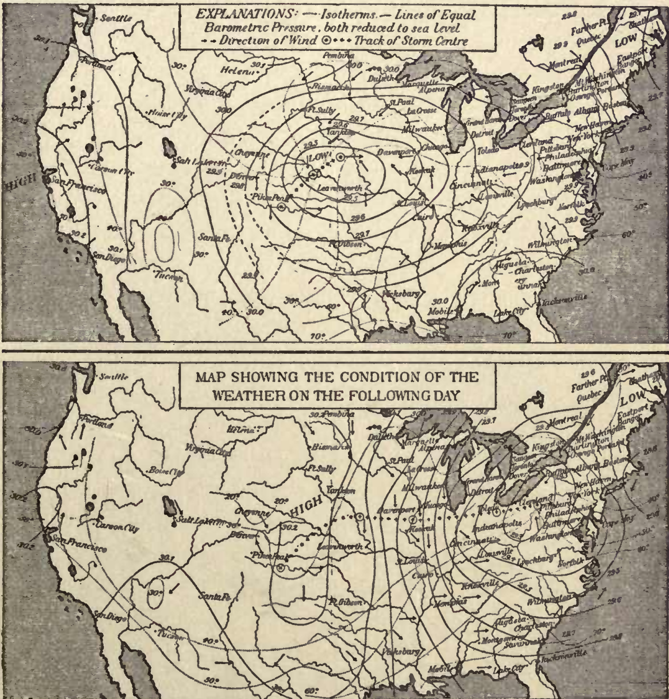
With this information, the officer to whom is entrusted the work of preparing the indication or forecast is able to see at a glance the exact conditions of weather existing at that time over the entire country. Armed with this knowledge, he should be able to make very good predictions as to coming changes in the weather; especially as the weather conditions in the west usually move eastwards. In point of fact, although sometimes the predictions by the Weather Bureau are unsatisfactory and inaccurate, it is claimed that nearly 85% of them are correct.

But the United States Weather Bureau does more than this. It publishes daily maps or charts on which are marked the actual weather conditions on each particular day, thus permitting the public to see the data on which such predictions are based, and, if they wish to do so, to try their hand at predicting.

Two such United States Weather maps can be found on page 181. They show the actual weather conditions all over the United States on two successive days in April, when a great storm centre was passing over the country. The track of the storm centre is marked by a series of crosses. By comparing the two maps you can see the path that this storm centre took during these two days. You will see by the upper map that there was on that day in April an area of low barometer in the States of Nebraska and Kansas. This area is indicated by an oval line known as an isobar, or a line connecting places where the atmospheric pressure as indicated by the barometer is the same. This is determined by the actual barometric pressure as obtained by telegraph from the observing stations. You will see marked on this line the figures 29.5, indicating that the pressure within this area is nowhere greater than 29.5 inches. Around this area of low barometer are a series of isobaric lines, showing barometric pressures increasing by one-tenth of an inch and marked, 29.6, 29.7, 29.8, 29.9, 30. These lines are generally, but not exactly, parallel to one another. The lower map shows the condition of weather that existed on the following day.

As will be seen, the storm center has increased in area and is now central over western Pennsylvania and other neighboring states.

Now, when an area of low barometer is formed at any part of the earth's surface, the air tends to run in from all



From Houston's Elements of Physical Geography

FIG. 39. MAPS OF THE UNITED STATES WEATHER BUREAU

sides towards that area. In other words, the wind blows in all directions towards the low area. The directions of these winds are indicated on the map by the arrows. An area of low barometer generally means an ascending current; and an ascending current generally produces clouds, accompanied by rain or snow. In other words, a low barometer is generally a *storm centre.*

The action of a low barometer, in causing the wind to blow towards it from all sides, is not unlike what would happen if several millions of tons of water could be suddenly removed from the surface at any part of the ocean by means of a huge bucket. There would be a hole or depression left in the water, and the pressure of the water on the floor of the ocean immediately below this depression, would be less than on the sides. The hole, however, would not remain. The water would flow in from all sides, and in so doing would acquire a rotary motion, just as you have seen the water in the bath-tub run out when the stand pipe is removed so as to permit the tub to empty. The direction in which the water in the ocean would rotate depends on the rotation of the earth, and, in the Northern Hemisphere, would be counter clockwise, or opposite to the direction of the hands of the clock; that is, from right above to the left and down; while in the Southern Hemisphere, it would be clockwise, or in the direction of the hands of a clock, or from left above to right and down.

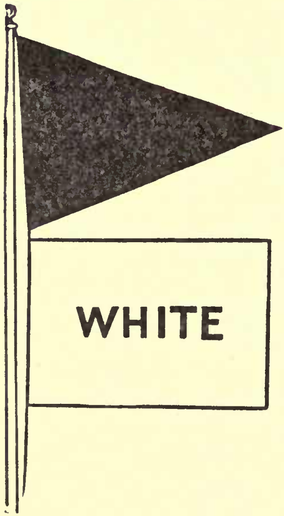


FIG. 40. WARM WEATHER FLAG

In the case of the wind this rotation or spinning would be like that of a top. You have probably noticed that when a top is caused to spin by being thrown on the ground, instead of remaining in one place it sometimes moves over the surface; that is to say, besides rotating or spinning, it progresses. Now, this is exactly what the storm centre does that is formed around the area of low barometer. It moves with the storm, over the country in a general easterly direction, as indicated on the second map. There should, therefore, be no difficulty in predicting the time of its probable arrival at different parts of the country.

But it is not only storms of rain, or snow, or high winds that thus move across the country from west to east; both hot and cold waves have similar movements, so that it is also possible easily to predict coming cold or hot weather.

When the Weather Bureau has prepared its forecast of the coming change in the weather, it next proceeds to send this information to different parts of the country. This is done by preparing accounts of the exact condition of the weather at that time all over the country, as well as of forecasts or predictions of probable coming changes in the weather, and telegraphing them to centres of distribution in the different States. Here they are printed, and at once enclosed in envelopes and forwarded to every post-office in the country, that can be reached by the best mail facilities before 2 P. M. the next day.

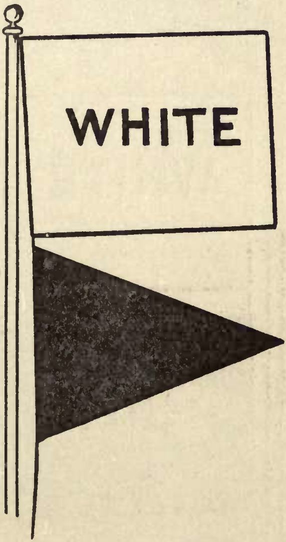


FIG. 41. COLD WEATHER FLAG

Another means of diffusing this knowledge is by the display of what are called weather signals, which are hung in prominent positions in different cities. During the day, flags are employed for this purpose, a square white flag indicating fair weather, and a square blue flag rain or snow. The approach of a hot wave, or warmer weather, is indicated by a triangular black flag, hung above a white flag as shown in Fig. 40. When the black flag is hung below the white, as in Fig. 41, the approach of cold weather is indicated. The approach of a cold wave is shown by the display of a square white flag with a square black centre. To indicate warmer, fair weather, followed by rain or snow, a triangular black flag is hung above a square white flag, below which a square blue flag is placed, as shown in Fig. 42. In a similar way, rain or snow followed by a cold wave would be indicated by a square blue flag hung above a square white flag with a square black centre, as shown in Fig. 43.

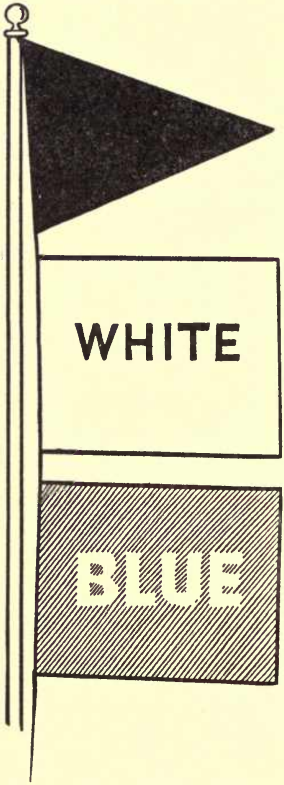


FIG. 42. WARM, FAIR WEATHER FOLLOWED BY RAIN OR SNOW

Signals, known as *storm signals*, consisting of a red flag with a square black centre, are displayed at all the ports on the Great Lakes and the Atlantic seaboard, whenever, in the opinion of the Weather Bureau, a wind dangerous to navigation is apt to occur at those ports, or within a distance of 100 miles therefrom, during the next twelve hours.

A signal known as the *information signal*, consisting, as shown in Fig. 44, of a long triangular red flag, is used to notify shipmasters that, if application is made to the local observer, information will be furnished them relative to an approaching storm which it is thought will be dangerous to vessels that are about to sail in certain directions.

Certain signals, called *cautionary signals*, consisting of a red flag with a square black centre, as shown in Fig. 45, are displayed only on the Great Lakes, when severe winds are apt to occur, dangerous to small vessels but not to well-equipped vessels. Lanterns with red and white lights are employed as signals for nights when flags would not be visible.

There can be no doubt as to the great value of the service the Weather Bureau is able to afford by reason of its predictions of coming changes in the weather. It has been truly said that the actual saving to shipping alone, that has been effected by the due warning of a single severe storm, may readily be more than sufficient to pay for all the expenses of the Weather Bureau for several years.

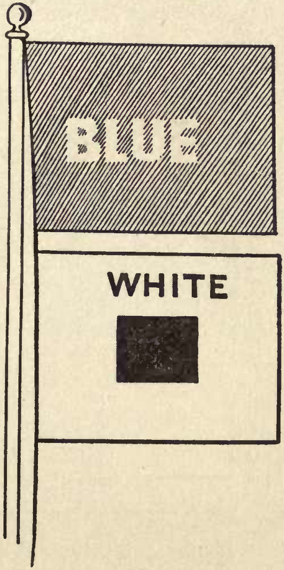


Fig. 43. Rain or Snow Followed by a Cold Wave

There is a certain kind of prediction which the Weather Bureau is able to make with great certainty, and that is *flood warnings.* Since the amount in inches of the rain that has fallen in a given time over different river valleys is accurately known, and the areas of their basins are also known, when these data are telegraphed to the central office at Washington, it is easy to calculate about what the rise of water in the principal rivers will amount to. As soon as the calculations show that in a given time the water will probably rise above a certain level known as the *danger level,* warnings are sent out to the cities and towns on the banks of such rivers. In the same way a knowledge of the rainfall and temperature makes it possible

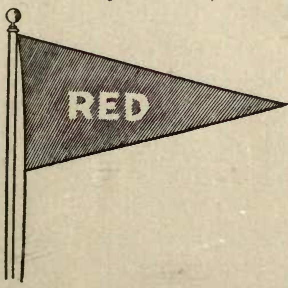


Fig. 44. Information Signal

to give warning of floods caused by the *movements of river ice* in the spring of the year.

Another direction in which the Weather Bureau has proved of great service to the country is in the announcement, made from day to day towards the approach of winter, of the probability of the freezing of the waters in the canals that might stop navigation; or of the temporary melting of the ice that might open canals sufficiently to enable icebound vessels to reach the terminals of the canal.

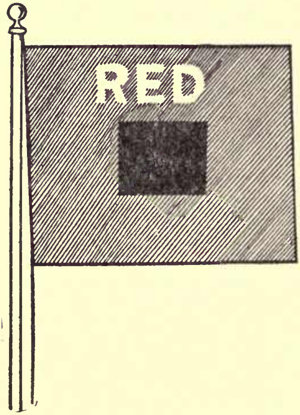


Fig. 45. Cautionary Signal

Weather bureaus have also been established for the prediction of weather changes in many of the principal countries of the world. The governments of Great Britain, Germany, France, Spain, Switzerland, Italy, Belgium, Austria-Hungary, Russia, British India, Japan, Australia, and New Zealand, like the United States, issue forecasts and publish weather maps.

In the United States, in certain parts of the west, great damage is sometimes done by *tornadoes*. These storms resemble *cyclones* and have been described in a previous chapter. They are especially frequent in the central and western parts of the Mississippi Valley. An attempt has been made by the Weather Bureau to predict the times of their probable occurrence, but our knowledge of these storms is too limited to permit such predictions to be of much value.

CHAPTER XIX

THE GROUND-HOG'S SHADOW AND OTHER WEATHER MYTHS

There was a time when nearly every one believed firmly in the myths, legends, or proverbs for predicting weather changes that had been handed down to them from past generations. Nor did this belief die out with our ancestors. In many cases it still exists. Some of these weather myths, being based on actual observations of well-known natural phenomena, are worthy of belief. Others being mere superstitions, are totally unreliable. In many cases these beliefs are expressed in verse, or, more correctly, in rhymes or jingles, for the composition in most cases is far from poetic.

In his book on "Weather Lore," Mr. Inwards has collected from a number of similar books many proverbs, sayings, and rules concerning the weather. I am sure it will interest you to hear some of them. I will therefore call your attention to a few only.

The "Saints' Days" for many generations have been supposed to rule the weather for longer or shorter periods. Chief among these is "Candlemas Day," or the Feast of the Purification of the Virgin, which was celebrated on February 2d. The name "Candlemas Day" was given to this feast because it was celebrated by a procession with lighted candles. There appears to have been a widespread belief that a clear, sunshiny "Candlemas Day" would be followed by a long period of cold weather.

The following are some of the many proverbs or rhymes concerning "Candlemas Day." The Scotch proverb says:

"If Candlemas Day be fair and clear,
There will be twa winters in the year."

Or, according to another proverb:

"If Candlemas Day is fair and bright,
Winter will have another flight.
But if Candlemas Day brings clouds and rain,
Winter is gone and won't come again."

But you may say that such proverbs were surely only believed in the past; highly civilized people like those now living in the United States would never believe such nonsense. But here you are wrong.

This belief in Candlemas Day weather still exists in many parts of the United States, but here the name of the Saint's Day has been dropped; the name Ground-hog Day is used in its stead. For the American form of the myth is that if the ground-hog comes out of its hole on the 2d of February and finds the weather cold and blustery, it stays out because it knows the winter is over. If it finds the sun shining so that it is able to see its shadow, it knows there is more winter to come, and therefore returns, and remains in its hole for six additional weeks.

A similar belief exists concerning the bear, the badger, or the woodchuck. Indeed, Ground-hog Day is in some sections also called Woodchuck Day.

According to the ground-hog myth the sun must be shining at noon for the sign to hold good; that is, the ground-hog must be able to see his shadow at this time, otherwise there is nothing indicated.

In Germany the ground-hog appears to be more reasonable, for there it is asserted that if he comes out of his hole and finds snow on the ground he walks abroad, since he knows that the winter is about over. But if he sees the sun shining, he goes back to his hole; but here only for four weeks instead of six.

A similar supposition exists in France where the following rhyme is common:

"At the day of Candlemas,
Cold in air and snow on grass;

If the sun then entice the bear from his den,
He turns round thrice and gets back again."

In Spain they say:

"When it rains at Candlemas,
The cold is over."

I suppose you have often noticed the great interest every one seems to take in the weather. When people meet, the character of the weather is very apt to be the first topic of conversation. This, perhaps, is natural, since so much of one's comfort depends on the weather, especially on holidays, or on days when picnics or excursions are planned that take us out in the open air.

Nearly all of us are apt to dwell unnecessarily on the unpleasantness of some particular kind of weather that does not suit us. This, I am sorry to say, is more frequently seen in older than in younger people.

You will very frequently hear people declare, when the weather happens to be unusually wet, dry, hot or cold, that they never remember experiencing such weather; that, when they were young, there never were such weather changes. Now, I have only to say to such people, that, although the weather certainly changes from day to day, as regards its heat or cold, its moisture or dryness, yet almost every year is on the average almost like other years. For example, in the United States careful observations concerning the condition of the weather or the climate as far back as 1738, show that the average climate has undergone no decided change since that time. You might remember this fact the next time you hear such assertions made.

The fact that the average climate of a country is so much the same, year after year, has given rise to a general belief (more or less correct) that unusually warm weather is apt to be averaged or made up for by unusually cold weather, and vice versa. If, towards the end of March, especially during the last three days of the month, the weather suddenly becomes unusually warm, March is said to have borrowed three days from April. These, it is claimed, are paid back by April taking on three days more of typical March weather.

Sir Walter Scott says that the last three days of March (according to the old calendar) were known as the *borrowing days.* If these days be unusually stormy, March is said to have borrowed three days from April.

A similar idea is conveyed in the following rhyme from Scotland:

"March borrowit from April,
Three days and they were ill;
The first was frost, the second was snaw,
The third was cauld [cold], as ever't could blaw."

It is the unusually warm days that March borrows from April that cause the early blossoms on the fruit trees and other vegetation. When, therefore, the colder weather comes in April (the borrowed days which March pays back), great loss to the crops often occurs from frost. It is the warm in days March, or at the beginning of April, that cause the blackthorn to bloom, and are followed by a cold period called the blackthorn winter. Hence the meaning of the saying: "Beware of the blackthorn winter."

There are many common sayings based on the well-known fact that rain is of greater value at certain times of the year than at others. For example, April is in most parts of the temperate zones of the earth the best time for the early rain; so we have in our country: "April showers bring May flowers." A saying in Portugal is as follows: "April cold and wet fills barn and barrel."

Sometimes predictions of the coming weather are based not on the weather during particular days, but during certain months of the year. Take, for example, the month of November. A belief exists that ice early in November indicates an open year. For example, we have the following rhyme:

"Ice in November,
Brings mud in December."

As regards the month of September, we have the following sayings:

"When a cold spell occurs in September, and passes without a frost, a frost will not occur until the same time in October." And again:

"If the storms of September clear off warm, all the storms of the following winter will be warm."

The feast of Martimas, which occurs on November 11th, was also believed to be a day like Candlemas Day. There is an old belief in England that the weather on this feast day determines the general direction of the wind for the coming winter.

"Where the wind is on Martimas, there it will be for the coming winter."

In the midland countries of Europe it is customary for the farmers to watch the weather on Martimas Eve carefully, since the weather at this time is supposed to govern the weather for some two or three months afterwards.

Perhaps some of the most foolish of the superstitious weather proverbs are those based on particular days of the week. I need not tell you that such proverbs are without any credibility. For example:

"When the sun sets clear on Wednesday,
Expect clear weather the rest of the week."

In France they have the following:

"Fine on Friday,
Fine on Sunday;
Wet on Friday,
Wet on Sunday."

There is also a very common belief that if it storms on the first Sunday of the month, it will storm every Sunday of that month.

There is another class of weather myths or proverbs that are based on such natural phenomena as the direction of the wind, the character and appearance of the clouds, especially their coloring at sunrise or sunset, or the appearance of the moon, that are sometimes reliable. Often, however, these appearances are so incorrectly interpreted that the predictions based on them are entirely valueless or misleading.

A similar class of predictions is based on the behavior of animals or of plants. To the extent that these actions or appearances are caused by existing weather conditions, they may indicate the kind of weather that is apt to follow them, and may therefore be more or less reliable.

Take, for example, weather predictions based on a careful examination of clouds and fogs. A fog or cloud indicates an actual weather condition and, when properly studied, may be profitably employed as indicating the coming weather. In all parts of the world, there are rhymes and proverbs based on cloud appearances. Thus Bacon says:

"If the sky clears, and the clouds commence to break out in the quarter opposite the wind, it will be fine; but if it clears up to windward, it indicates nothing and leaves the weather uncertain."

So our Saviour says, speaking of weather signs in Palestine:

"When ye see a cloud rise out of the west, straightway ye say, there cometh a shower; and so it is." (Luke xii, 54.)

Inky clouds generally foretell rain. Light clouds driving across heavy masses show wind and rain, but, if alone, they indicate wind only.

The peculiar speckled condition assumed by the sky when the cirrus clouds collect in spots or blotches resembling the scales on the back of a mackerel, is known as a *mackerel sky.* A mackerel sky is believed by some to indicate wind and rain, as shown by the following rhymes:

"Mackerel sky and mares' tails,
Make lofty ships carry low sails."

And so, too, the following:

"Mackerel scales,
Furl your sails."

Sailors have a superstitious belief that they can "whistle up" a wind, and can, moreover, determine its strength from the strength of the whistle, a soft whistle bringing a breeze, and a loud whistle, a gale. Some declare that scratching the mainmast, or throwing a ha'penny overboard, will also bring a wind.

Other natural phenomena are employed for predicting coming weather changes. Among these is the St. Elmo's fire; the faintly luminous tongues of flame sometimes seen issuing from the ends of non-conducting bodies when in connection with the earth. St. Elmo's fires are due to an electric discharge known as the brush discharge, and will be described in a subsequent chapter.

When seen at sea, St. Elmo's fire was believed by the ancients to indicate a coming storm, and it was thought this storm would be especially severe if the tongue of flame did not remain at one place, but shifted its position.

Shakespeare thus refers to St. Elmo's fire in the "Tempest."

"Sometimes I divide
And burn in many places; on the topmast,
The yards and bowsprit would I flame distinctly.
Then meet and join."

And,

"Last night I saw St. Elmo's stars
With their glimmering lanterns all at play.
On the tops of the masts and the tips of the spars,
And I knew that we should have foul weather that day."

Many weather proverbs are based on certain actions on the part of animals. It is probable that, in many cases, animals possess more highly developed senses to observe natural phenomena from which coming weather changes can be foretold than does man. Many weather proverbs are based on their actions.

While many of these proverbs must be regarded as foolish, yet some can be relied on.

It is generally believed that the unusual howling of dogs portends a storm. It is not impossible, however, that it simply indicates that the poor animal is hungry and wants its food, or is suffering from the effects of over-indulgence.

A general belief exists among the Esquimaux that when their dogs, while temporarily resting, begin to burrow in the snow, it is a sign of an approaching heavy snowstorm.

In Scotland it is asserted that cats are especially apt to scratch a wall or post immediately before the coming of a strong wind; wash their faces before a thaw; and to sit with their backs to the fire before a snow. It is not improbable, however, that in most cases they scratch their claws for the purpose of sharpening them, and wash their faces for reasons of personal cleanliness, and sit with their backs to the fire because they wish to get warm.

Some animal weather signs are still more ridiculous. For example: in the northern counties of England the following belief is prevalent:

"If the cat washes her face over the ear
'Tis a sign the weather will be fine and clear."

So, too, in New Jersey, the following is believed concerning a cow:

"When a cow endeavors to scratch its ear
It means a shower is very near.
When it thumps its ribs with angry tail
Look out for thunder, lightning, hail."

It is said that one morning Sir Isaac Newton met a cowherd who told him he would soon be overtaken by a shower. Sir Isaac, being a natural philosopher, carefully examined the heavens and finding them cloudless, went on. Being afterwards overtaken by a severe storm, he rode back to the cowherd and inquired on what he had based his prediction. The philosopher was surprised when he received the following answer:

"Well, sir, all I know is that when my cow twirls her tail in a certain way, a shower will come."

Sheep and goats are credited with an intimate knowledge of coming weather changes. They seem unwilling to leave their pastures if it is going to rain the next day. When old sheep turn their backs to the wind and remain so for some time, it is believed that wet, windy weather is coming.

Birds, especially migratory birds, show considerable knowledge of coming changes. When they take their flight earlier than usual for warmer regions, an early, cold winter may be looked for. When birds capable of flying for great distances remain around their nests, wind and rain may be expected. These are generally reliable indications.

When the cock crows late and early, and claps his wings more than usual, rain may be expected. This is expressed in the following rhyme:

"If the cock crows going to bed,
He will certainly rise with a watery head."

In some parts of the country, it is believed that, by looking at a flock of wild geese in flight, various letters or figures may be distinguished that will indicate the number of weeks of frost that are to follow.

It would certainly seem as if certain birds had some way of telling the probable coming of a flood. According to Swainson in his "Folk-Lore of British Birds," birds, whose homes are on the banks of the Thames, raise their nests shortly before the coming of heavy rains, to prevent the eggs from being chilled by the water.

In some parts of the world the peacock is believed to be able to foretell coming rainy weather. Thus:

"When the peacock loudly bawls,
Soon we'll have both rain and squalls."

Theophrastus declared that, if the crow caw thrice immediately after daybreak, fair weather will rule the day, but if it caws in fine weather a storm is indicated.

In Scotland it is believed that if the raven cries first in the morning, the day will be fair, but if the rook cries first, the day will be stormy.

In portions of England, although the weather may be unsettled and rainy, yet if the robin takes its stand on the topmost twig of a tree, and sings cheerfully and sweetly, it is believed to be an unerring sign of fine weather. But when, though the atmosphere is dry and warm, he sits with melancholy chirping in a bush, or low down in a hedge, the chances of bad weather are excellent.

In Spain it is believed that the ordinary blood-sucking leech, commonly employed in medicine, is a reliable weather prophet, and that coming changes in the weather can be determined by changes in the leech's position when kept in a jar of water.

You will be surprised to learn that a Mr. Merryweather actually contrived an apparatus by means of which one of twelve leeches confined in a vessel of water, rang a little bell when a tempest was indicated. I suppose the officials of the United States Weather Bureau would have been jealous of these rival weather prognosticators; for Mr. Merryweather actually exhibited a *leech tempest detector* at the Exhibition of 1851, in London, and urged the government to establish *leech storm-warning stations* along the coast.

Honey bees are believed to be good weather prophets. In Scotland, they assert that when many bees enter the hive and none issue from it, rain may be expected. Virgil speaks thus regarding the bees:

"By turns they watch, by turns with curious eyes,
Survey the heavens, and search the clouded skies
To find out breeding storms and tell what tempests rise."

Longfellow in "Evangeline" thus alludes to this power which bees are said to possess.

"All the signs foretold a winter long and inclement.
Bees, with prophetic instinct of want, had hoarded their
honey,
Till the hives overflowed."

As you might imagine would be the case, spiders are considered great weather prophets. Many believe that by carefully watching these animals, they can predict coming changes in the weather. For example, Bacon says:

"Spiders work hard and spin their webs a little before wind, as if desiring to anticipate it; for they cannot spin when the wind begins to blow."

It is said that when spiders are seen crawling on walls more than usual, it indicates that rain will soon come. This sign seldom fails, especially in winter.

When the spiders make new webs, and also when they cleanse their webs, fair weather is indicated. When they continue spinning their webs during the rain, the weather will soon clear.

House flies are also credited with being good weather prophets. When the flies cling to the ceiling or disappear, rain may be expected. When the flies are more troublesome than usual, a change of weather, generally rain, is indicated.

In a similar manner when gnats or little flies are more than usually troublesome, you may look out for rainy weather.

Another set of weather prognostications is based on certain peculiarities of different species of the vegetable kingdom. In the midland counties of England, it is believed that when the oak comes into leaf before the ash, fine weather during the harvest is indicated; but when the ash comes out before the oak the harvest will be wet. This is seen by the following Shropshire, England, rhyme:

"When the ash is out before the oak,
Then you may expect a choke [drought].
When the oak is out before the ash,
Then you may expect a splash [rain.]"

The Apache Indians believed that when the ears of Indian corn are covered with thicker and stronger husks than usual the coming winter will be a hard one.

There is a very common belief in portions of the North Temperate Zones that the character of the coming weather may be read in the thickness of the onion's skin. When thin and delicate, a mild winter is indicated, but when thick and heavy, look out for a cold winter. This belief is indicated in the following rhyme:

"Onion's skin very thin,
Mild winter coming in;
Onion's skin thick and tough,
Come winter cold and rough."

It is believed by some that the presence or absence of a shower may be foretold by the appearance of the petals of certain wild flowers. For example, when the flowers of the chickweed are only half open during rainy weather, it is a sign that the wet will last long; but when the chickweed expands its leaves boldly and fully, fine weather is apt to follow.

The heavenly bodies, especially the sun and moon, as well as the stars, have long been regarded as furnishing the best kind of indications of weather changes.

When the sun's rays are visible in the air, the sun is said to be "drawing water," and it is supposed that rain is indicated. This, however, is one of the many popular fallacies concerning the atmosphere. The appearance is due to the shadow of the clouds, and, therefore, is worthless as indicating coming changes in the weather.

When bright patches of sunshine break through an otherwise stormy sky, the sun is said to be "making holes in the clouds for the wind to blow through."

In winter a red sky at sunrise foretells a steady rain the same day. In summer, however, a red sky betokens occasionally violent showers. In both cases, however, a wind may be expected. Thus Shakespeare says:

"A red morn, that ever yet betokened
Wreck to the seamen, tempest to the field,
Sorrow to shepherds, woe unto the birds,
Gusts and foul flaws to herdmen and to herds."

The appearance of the heavens at sunset is also employed in weather prognostications. According to Bacon the sun setting behind a cloud forebodes rain the next day. But actual rain at sunset is rather a sign of wind.

In Scotland the following rhyme speaks for itself:

"Evening red and morning gray,
Help the traveller on his way.
Evening gray and morning red,
Bring down rain upon his head."

Sometimes the conditions of the atmosphere, as we shall see in a subsequent chapter, are such as to produce the appearance of bright spots somewhat resembling suns and moons, that are seen where complicated circles of light intersect each other. These are called *parhelia* or *mock suns,* and *paraselene* or *mock moons.* When two or three mock moons appear at a time, usually two or three days after the full moon, storms of rain and wind and other unseasonable weather are apt to follow and continue for a long time. Thus Shakespeare, in (King John, iv, 2) says:

"My lord, they say five moons were seen tonight.
Four fixed; and the fifth did whirl about
The other four in wondrous motion."

It is not surprising that such phenomena as thunder and lightning should have been regarded in all ages as indicating coming changes in the weather. The Zuni Indians were careful to mark the direction from which the first thunder came in the year, since that would determine the weather during the coming season.

Many years ago, and to some slight extent at the present time, the almanac has been a medium for the diffusion of weather predictions. As you know, an almanac is a little book compiled once a year containing a series of tables giving all the days of the week and the corresponding days of the month throughout the year. Besides this, it usually contains certain information concerning the times of the rising and setting of the sun and moon, and the phases of the moon, the height of the tide, and the position of the heavenly bodies generally.

The almanac appears to have been employed as a substitute for the newspapers long before printing was invented. The earliest almanacs consisted of a four-sided stick of wood containing notches for indicating *Sundays* and other fixed days of the year.

At one time most of the almanacs were expected to contain predictions of the weather for every day of the year. I need not tell you that such predictions are generally unreliable. To the extent, however, that a prediction for each day was based on the actual weather for the corresponding day of the previous year, such predictions sometimes proved true. For instance, one would not be apt to predict snow for July or August, or very high temperatures for January or February. Such almanacs were successful when their predictions, like those of the Delphic Oracle, were ambiguous, so that after the day had passed, it would be possible to assert that the prediction properly described the actual kind of weather that had occurred. It soon began to be recognized, however, that the almanacs were too unreliable to be trusted; for, as it is said in Denmark:

"The almanac writer makes the almanac, but God makes the weather."

CHAPTER XX

THE DUST OF THE ATMOSPHERE

Dust, or fine particles of various solid substances, is almost invariably present in the air, so that dust can, perhaps, be regarded as a regular constituent of the atmosphere. Dust particles are often of sufficient size to fall rapidly to the ground. At other times they are so minute that they remain floating in the air for an almost indefinite period. This is especially the case with the particles that have reached the higher regions of the atmosphere.

The quantity of atmospheric dust varies greatly in different parts of the earth, and at different heights above the level of the sea, as well as at different times of the day or year. Generally, however, the quantity is greater in cities than in the country; in crowded rooms than in the open air; near the surface of the earth than in the higher regions of the atmosphere; during windy days than when the air is calm; and during damp weather than when the air is dry.

The dust of the atmosphere consists of fine particles of mineral, vegetable, or animal origin.

Mineral dust may consist of particles of dry soil carried into the air from the ground by the action of the wind; of saline substances, carried into the atmosphere as spray by the wind blowing against the surface of the ocean, and crystallized on the evaporation of the water before it has fallen back again into the ocean; of various mineral particles that have been thrown out by volcanoes into the higher regions of the air during eruptions; of minute particles of various raw materials that have been thrown into the air from manufacturing establishments during the processes of sawing, filing, polishing, burnishing, grinding, crushing, pulverizing, spinning, or weaving of different raw materials; of smoke particles thrown into the air from the chimneys of manufacturing establishments; or even minute fragments of meteorites that fall on the earth from the regions outside our atmosphere.

Dust particles of mineral origin are found in all parts of the atmosphere. Owing to their weight dust particles of this character are constantly settling or falling; they exist, therefore, in greater quantities in the lower regions of the air. They are not, however, absent in the higher regions, since the atmosphere, when tossed about by the wind, can readily carry the finer dust particles to great distances above the surface of the earth.

Dust particles of vegetable or animal origin are found almost entirely in the lower regions of the atmosphere. Dust of this character consists of minute fragments of decaying animal or vegetable matters that are either carried into the air by the wind, thrown into it with the air that is breathed out from the lungs of the animals, or carried up into the air by the heated currents that arise from their bodies. Since this kind of dust consists of decaying and putrefying materials, it is generally characterized by a disagreeable odor. Besides these minute dead and decaying fragments, there are always found in the air, especially in its lower regions, minute forms of life called *micro-organisms*. These, however, are to a great extent limited to the lower parts of the atmosphere.

Micro-organisms are found in large quantities only in the air over the land. Over the ocean, at distances of about 100 miles from the nearest land, the air is almost entirely free from them.

In the lower layers of the air, over densely populated cities, especially in parts of the world where fogs are common, the number of micro-organisms is apt to be very great. Analyses of air from the streets of London and Manchester, England, show that here their number is so great that a man of average size will take into his lungs by breathing no less than 4,000,000 every hour.

The number of these living germs, or bacteria, varies in the same district with the season of the year; it is smaller in winter, increases rapidly during the spring, attains its maximum in the summer, and rapidly decreases during the autumn.

The quantity of bacteria present in our food is even greater. In a few swallows of ordinary milk there are taken into the stomach at least 25,000,000 bacteria. How is it then, you will probably inquire, if we take these germs so freely into our lungs and stomach, that any of us are still alive. Fortunately, by far the greater number of these organisms are entirely harmless, while some of them even produce beneficial results. The dangerous ones do not appear, as a rule, to produce any bad effects on healthy animals. Indeed, in many cases, they are even digested by such animals and thus become a source of nourishment.

The presence of dust particles in the atmosphere produces many effects, all curious and some very wonderful. For example: these dust particles must be present in the air to permit the ready condensation of the invisible water vapor of the air into fogs, clouds, dew, etc., on the loss of a certain amount of its heat. Moreover, it is to the same dust particles, together with the minute drops of water that form clouds, that the blue color of the sky is due, as well as the wonderfully beautiful tints of sunrise and sunset, and the curious appearances of haloes around the sun and moon. Since we will discuss these phenomena under their proper heads in other parts of this book, we will now content ourselves with the study of some of the ordinary dust particles that are present in the air.

That large quantities of dust are constantly falling on the earth from the air like a gentle shower, is seen from the rapidity with which dust settles on everything in a house, covering it with a more or less thick layer, unless the dust brush and the feather duster are kept in frequent use. Even in a well kept house, the dust falls on everything; on the carpets, rugs, and furniture; on the books in the book-cases; on the mantelpieces and on the ornaments on them; on the picture frames and the pictures; on the walls or ceilings of the rooms; and, perhaps, especially on the people in the house.

But this settling of dust does not stop here. It not only falls on things that are directly exposed to the air, but it also accumulates on objects placed inside of tightly closed drawers, such as the drawers of bureaus or desks; inside closets and trunks; and on the books that are placed inside book-cases provided with so-called dust-tight glass doors. Indeed, it appears practically impossible to so close a space that has to be frequently opened by means of a door or drawer, as to prevent the dust from entering. It is not difficult to find the reason for this; the finer particles of dust can enter almost anywhere that air can enter.

It is by reason of the differences of temperature between the air inside and the air outside closed spaces, and the consequent differences in pressure, that the air is driven into and out of such spaces, and thus deposits its burden of suspended dust particles.

What, then, are the substances found in different kinds of dust? Mineral dust consists of particles of carbon or soot, of flint or sandy matters, or of various substances obtained directly from the soil, such as minute fragments of limestones, building-stones, brick dust, etc. Organic dust consists of the fibers of various vegetable and animal matters, such as cotton, linen, wool, silk, etc., from the fabrics employed for clothing, carpets, curtains, etc.; the scales of the epidermis or human skin, of particles of starch, grains of pollen, etc.

Perhaps the commonest kind of mineral dust found in the air of houses consists of particles of carbon or soot.

These particles are thrown into the air by every lighted candle, oil lamp, or gas flame.

The ordinary tallows or waxes employed in candles, the oils that are burned in lamps, and the gas burned in gas jets, consist of various hydrocarbons, or compounds of hydrogen and carbon. Now, while it is possible to burn any of these hydrocarbons so that all the hydrogen and the carbon will combine with oxygen, and while, in point of fact, an effort is made to so combine it where the object is to obtain the greatest amount of heat, yet, if the object is to obtain light, care must be taken to ensure an incomplete burning, or combustion, such as will leave some of the carbon free.

It is by no means an easy matter exactly so to regulate the amount of air supplied to a lamp or gas flame as to produce the greatest amount of light. If too much air is supplied, the hydrocarbons are completely burned, and a flame results, possessing great heat, but almost no light. If too little air is supplied, too many carbon particles are liberated and a smoky flame results. It is only when just the proper amount of air is supplied that the amount of light is greatest. In the candle this regulation in the amount of air is effected by the cutting, or snuffing, of the wick as soon as it becomes too long and smoky; in the oil lamp; by turning down the wick; and in the gas flame by partially turning off the gas. In all these cases, you can notice that the luminous source produces its best light when the flame is most free from smoke, and the light contains fewest of the reddish or yellow rays.

Every candle, oil lamp, and gas flame throws into the air a great number of dust particles consisting of carbon or soot, for very few of these particles are consumed. The remainder pass into the air from the flame, and, cooling, settle on the ceiling or walls of the room, or on different objects with which they come in contact.

The number of carbon particles that are thus thrown into the air is very great. It has been estimated that millions upon millions of soot or carbon particles are produced during the burning of a single foot of illuminating gas of the quality generally employed in the United States and Europe.

If you examine some of the dust that has been removed from the floor of a room, especially if it contains no carpet, you will be able to see, even without the use of a magnifying glass, particles of various fibrous substances, such as cotton, linen, hemp, wool, silk, etc. If you happen to live in this house it is almost certain that some of these fibers are from the clothes you have worn and are possibly still wearing.

The presence of grains in the atmosphere, of pollen, or dust from flowers, of course varies with the season of the year, this ingredient being found only during the time certain flowers or trees are in bloom. It is of course more apt to be found in the air of the country than in that of the city.

The character of the dust particles in the atmosphere will necessarily depend on the character of the land surfaces in the neighborhood. In districts containing chalk deposits, chalk particles will predominate; in sandy districts, flint particles; and in places where clothes are worn out, such as in the rooms of houses, particles consisting of various fibrous materials. So, too, in the air of rooms of different manufactories, the character of the dust particles will depend on the character of the work carried on.

Certain trades or occupations are so very unhealthful that the average lifetime of the workmen engaged in them is much shorter than in other trades. In many cases this increase in the number of deaths can be traced directly to the presence of dust particles in the air. It is, of course, not so much the number or amount of these particles as it is their character; for some dust particles are much more injurious than others. Some are actually poisonous, others merely irritating, and still others, under certain circumstances, are almost harmless.

Dr. Charles Harrington, in his work on Hygiene, the science of preserving the health of individuals or communities, divides the atmospheric dust in the air of various manufacturing establishments into two classes; namely, *poisonous dust* and *irritating dust.*

The most dangerous variety of poisonous dust consists of various coloring matters containing compounds of arsenic or copper, especially the green pigments employed for wall papers, or artificial flowers. Workmen engaged either in grinding or preparing these coloring matters are very apt to be poisoned by them.

Lead dusts are especially injurious. Although, weight for weight, arsenic dusts are generally more poisonous than lead, yet lead forms what is called a *cumulative poison.* That is, it possesses the power of collecting in the system until a sufficient amount has accumulated to produce serious results. Small doses of lead can be taken into the system without producing any appreciable results. The poisonous substances, however, remain in the system until a certain quantity has accumulated, when the poison suddenly manifests itself. It is for this reason that lead poisoning is of such frequent occurrence.

Irritating dusts are produced in many trades. The dust produced by grinders of cutlery, consisting as it does of fine particles of steel, is exceedingly dangerous. This is especially the case when the articles ground are small, since here a very high velocity is employed in the grinding wheels.

Among other kinds of irritating dusts that are apt to shorten the lives of the workmen, are those produced by the grinding of glass, the polishing of gems, or the cutting of stone generally. The preparation known as *mica dust* is especially dangerous. This variety of mineral dust is made from mica of a silvery color, and is employed for the ornamentation of wall papers. The mica is ground into exceedingly fine particles which remain in the air for a long time and, when taken into the lungs by breathing, are apt to produce very injurious effects.

There are various kinds of vegetable dusts. Of these, dusts produced from different kinds of wood do not appear to be dangerous; nor are the dusts produced by the thrashing of grain or by the grinding of grain in mills apt to produce very serious effects on the health of the workmen. Probably the most dangerous kind of vegetable dust is to be found in dust from cotton or flax mills, especially where kaolin is employed.

Animal dusts consisting of minute particles of wool, silk, feathers, bristle, hair, fur, bone, shell, and ivory are apt to produce serious effects when breathed by workmen.

Now, without attempting to go into details as to the different effects produced by these various kinds of dusts on the health of the workmen, I wish to endeavor to call your attention to a very important fact; viz., that, as a class, the workmen who are exposed to irritating dusts in the air they breathe are especially apt to die from pneumonia, consumption, or various digestive disorders.

But pneumonia and consumption are diseases that are caused by the presence in the air of special disease germs, or bacilli. You will, therefore, naturally inquire why it is that a workman constantly exposed to the breathing of irritating dusts is more apt to contract such diseases than others.

The explanation is quite simple. We are all apt, at one time or another, to breathe into our lungs air containing the particular bacillus, or disease germ, capable of producing either pneumonia or consumption. If we are in good health, these germs may enter the body without bad effects. Suppose, however, the system is run down; that by breathing in an unusual quantity of dust of an irritating character a cough is set up. If this cough becomes chronic, or continuous, an increased secretion of mucus is produced, when, in the soil so prepared, a particular disease germ finds a lodgment and, rapidly multiplying, results in the setting up of one or the other of these dread diseases.

In the neighborhood of active volcanoes during an explosive eruption, the air frequently becomes laden with extremely fine particles of hardened lava, known as volcanic dust, together with coarser particles known as volcanic ashes. Owing to their greater weight the volcanic ashes soon fall back again on the sides of the volcano, while the volcanic dust particles, thrown high into the air, remain suspended in it for days, months, and even years.

The quantities of volcanic dust that at times issue from the craters of volcanoes are almost incredible. Not only is the ground in the immediate neighborhood of the crater covered with layers of ashes and dust many hundreds of feet in thickness, but frequently districts many hundreds of miles from the crater are similarly covered. This has been especially the case in such explosive eruptions as those of the volcanoes of Krakatoa, Vesuvius, Etna, and others, as has been explained in the book called the "Wonder Book of Volcanoes and Earthquakes."

The first effect of volcanic ashes or dust is to kill the vegetation over the areas on which they collect, especially in districts where the ashes fall to the earth while in a red hot condition. In process of time, however, and that generally a short time, the exposure of the ashes or dust to air and moisture results in the formation of a very fertile soil. The great wheat fields of Montana and other portions of the Western United States owe their fertility to immense showers of volcanic ashes that escaped, a very long time ago, from the many volcanoes in the western part of the United States; volcanoes that are now in what are called an extinct condition, but which were then active and may at any time again become active.

CHAPTER XXI

PRODIGIES OF THE ATMOSPHERE

I have told you so many wonderful things occurring in the atmosphere that can very properly be regarded as prodigies, that I somewhat fear the above chapter heading may be misleading.

But what I especially refer to are phenomena of such a wonderful nature that I think they can best be called prodigies.

If what appeared to be copious showers of blood, milk, or ink, or real showers of sulphur, toads, frogs, or fish, were poured down from the sky in place of rain or snow, I am sure you will agree with me that such unusual phenomena could very properly be called prodigies.

The falling of what appears to be a *shower of blood* from the sky, while not a common prodigy, still has occurred a very great number of times in different parts of the earth. Homer tells of a shower of blood that fell on the heroes of Greece which, quite naturally, was regarded as a very inauspicious sign.

Another notable shower of blood is said to have occurred in parts of Italy in the neighborhood of Rome, in the 14th year of the Roman Era. In the year A. D. 570 and again in A. D. 572, there were showers of blood which continued constantly falling through the sky for two days in parts of Italy; while, in the years A. D. 587, 687, 626, and 646, blood also fell in showers from the sky in the same country.

It is not surprising that ignorant people became greatly alarmed at such wonderful events. When it happened that a shower of blood either preceded or followed some bloody battle, it was generally regarded as predicting a battle that was to come, or a still bloodier battle that was to follow that which had already occurred.

I am indebted, among many other authorities, for most of the examples of prodigies mentioned in this chapter to Flammarion, who cites a number of prodigies, described by M. Grellois and others, that have occurred at various dates from the Christian Era down to the present time.

According to Gregory of Tours, a shower of blood fell over the country around Paris, during A. D. 582. This bloody rain, staining the clothes of the people on whom it fell, produced in them such a repugnant feeling that they tore their clothes off in horror.

A bloody rain of a similar character occurred at Constantinople in the year A. D. 652; and two years afterwards, a bloody rain, while falling, imparted to the heavens such a reddish color that they seemed to be on fire.

During the year A. D. 1117, great terror was excited throughout Lombardy by showers of blood, accompanied by such awful subterranean noises that all the bishops of the church were assembled at Milan in order to consider the cause of these terrible happenings.

In the year A. D. 1181, a rain of blood continued for three days in France and Germany, while, at the same time, a luminous cross was visible in the sky. In A. D. 1571, the fall of bloody rain was so great during the night at Einden, that the grass and other objects for five or six miles around assumed a dark purplish color.

I am sure it is not necessary for me to tell you that these so-called showers or rains of blood have nothing whatever supernatural about them, but can be explained in a very simple manner. For example, take the shower of blood at Aix in 1608, which caused blotches of blood to appear on walls and other objects outside the city. A naturalist, named M. de Peiresc, carefully examined some of the alleged blood drops, and discovered that they consisted of the excrements of a species of butterfly of which there were then great numbers in the town. But the people appeared to prefer to regard them as miraculous, so that comparatively few were willing to accept the true explanation.

You must not suppose, however, that all showers of blood are caused by butterflies or other insects. In cases where *bloody rains* actually fall from the skies, the color is due to various red mineral matters, consisting of dust washed from the atmosphere to the surface by the falling rain, which thus becomes blood-colored. For example, the showers of blood that fell throughout Lombardy in the year 1117 were almost certainly due to the presence of a red volcanic dust that had been thrown into the atmosphere during an eruption. In some other instances, bloody rains have been traced to the presence of a red earth, carried into the atmosphere as dust by a strong wind blowing over a mountain in the neighborhood, and afterwards washed out by the falling rains.

It is not always by means of volcanic eruptions that clouds of red dust are carried into the atmosphere. In, perhaps, the greatest number of cases, especially in regions that are at a distance from active volcanoes, it is strong whirlwinds, or other powerful winds, especially when they cross extended desert areas, that load the air with fine dust particles. As you will remember in reading the chapter on storms and cyclones, it is during these disturbances that the wind attains enormous velocities, so that it would be possible to raise very fine particles of sand and carry them quite long distances from the desert. This is the case in such extended deserts as are found in Northern Africa and in Central Asia, as well as in parts of Europe and America.

Another class of prodigies, not, however, so common as showers of blood, are those in which a substance closely resembling milk appears to be rained down from the sky. In the year A. D. 620 streams of milk are said to have flowed into a Roman lake. In A. D. 629 a *shower of milk,* accompanied by oil, fell from the sky. There is but little doubt that these phenomena are due, either to white dust particles thrown into the air during volcanic eruptions, or, more probably, to white or chalky dust blown from some portion of the earth's surface into the air by a powerful hurricane.

It is probable, however, that the *streams of milk* above referred to as sometimes observed flowing in rivers, have been confounded with showers of milk. The so-called milk streams are very common phenomena in some parts of the world, where they are due to rain washing over a soil which contains loose particles of chalk or other material, and thus acquires the color of milk and even of cream.

Sometimes, though much less frequently than the showers of milk or blood, there falls from the clouds a blackish fluid that closely resembles *ink*. Like the preceding so-called prodigies, this is probably due to the washing down from the atmosphere of particles of very fine suspended black dust.

Somewhat similar prodigies are seen in falls of colored snow in certain parts of the world. In various localities of the Arctic zone it is common to find fairly large areas of *bright crimson snow*, and in other places areas of bright green-colored snow. In both cases the snow owes its color to the presence of a minute form of plant life known as *algæ*, which multiplies with such great rapidity that a snow surface containing so small a quantity as to scarcely produce a coloration, soon acquires a deep crimson color. The coloring matter in the algæ is soluble in water, so that, as the snow melts, the water sinking through that which remains, stains it, in the case of crimson snow, with a pinkish tint that sometimes extends several inches below the surface. Dr. Kane and other Arctic explorers in North America, report many cases of crimson snow. So, too, did Nansen, the Arctic explorer who made that curious voyage in the "Fram" during which he remained on his vessel—which had been especially built to resist the tendency of the ice to crush it—and who hoped, in this manner, to drift across the pole.

Sometimes a *yellow rain* falls from the sky. There is, however, nothing astonishing in this, since it is due either to finely divided particles of sulphur, or brimstone, thrown into the air during a volcanic eruption, or to an immense quantity of *pollen dust* carried into the air during the bloom of certain species of flowers. There would be no difficulty, however, in determining to which of these sources a yellow rain is due, since an examination with a moderately strong magnifying glass would, in the case of a pollen shower, indicate the character of the yellow material from the very beautiful forms that pollen possesses.

There is, however, another kind of a yellow rain that appears to be due to the presence of a yellowish dust, colored, among other things, by an oxide of iron.

Showers of sulphur are not uncommon in the neighborhood of volcanoes. It is said that a heavy shower of this character fell at Copenhagen on the 16th of May, 1646, and that a similar sulphur shower fell in Norway on May 19th, 1665. Indeed it is unnecessary to go so far back to find instances of sulphur storms. As I am writing this chapter, on the 14th of May, 1907, I recall reading in the morning papers an account of a rain of finely divided sulphur particles that fell the day before, in portions of Italy, in the neighborhood of the volcanoes of Stromboli and Etna.

But I am not through telling about the curious things that have been known to fall from the sky. So far we have only described phenomena due to the presence of exceedingly fine dust particles, or other microscopic particles in the air.

At times, however, there are rained down from the sky objects possessing considerable size. The following articles have been known beyond any question to have fallen, apparently from the clouds: oranges, frogs, toads, fish, and various kinds of insects; and in one case, though I would not advise you to put too great faith in the correctness of this particular story, a calf was actually rained down from the air on the earth. Let us take up these things in order and see if we can explain them.

First, as to the *shower of oranges:* This occurred on July 8th, 1833, at a place near Naples. There was nothing remarkable about this, however, when you understand that it was caused by a waterspout that, passing over the place, swept the oranges out of two large baskets, and, after keeping them in the air for fully ten minutes, the advancing column of water carried them a considerable distance before they fell to the ground.

As to frogs, it is said that, many years ago, frogs and fish fell from the sky in several parts of Greece, in such great numbers that the houses and roads were covered with them, so that it was impossible to walk without treading on them; and that on the death and decomposition of their bodies, such an extremely disagreeable odor was produced that it was impossible to live for some time in that neighborhood.

It appears that showers of frogs and fish are quite common phenomena in some parts of the world. Of course, these animals have been carried into the air either by waterspouts, or by powerful winds, and afterwards dropped to the ground.

There is nothing very remarkable about showers of locusts; at least there is no difficulty in explaining how they can get into the air, since their power of flight renders this self-evident. At times, however, locusts multiply with such wonderful rapidity, and collect in such enormous numbers, that their host can certainly be correctly characterized by the term prodigious, even if the occurrence itself could not be classed among the prodigies.

Before closing this chapter, I wish to describe to you some phenomena connected with the formation of fogs. Not, however, of those fogs that are caused by the presence of moisture in the air, but fogs, or, what would, perhaps, be more correctly called *haze*, due to the presence of dust particles or particles other than the drops of water present in ordinary fogs. These are distinguished from ordinary fogs by the name *dry fogs.*

A dry fog that occurred during 1783 created great terror, even among educated people, in a large part of the world. In the opinion of Chladni, a German physicist, who has made a number of investigations in acoustics as well as in other branches of physics, this fog was due to the presence of extremely attenuated matter, possibly of the same nature as that which forms shooting stars or meteoric stones, that had become entangled in our atmosphere while our earth was moving through nearly empty space. Indeed, it may have been matter in that nebulous state in which it is believed that all the matter of the solar system originally existed. The diffusion of an unknown substance, possessing unknown properties, through the atmosphere, can, I think, fairly be regarded as a prodigy.

This remarkable dry fog of 1783 was first seen at Copenhagen on May 24th. By June 6th it had reached La Rochelle, France, and on the 18th of June it was at Göttingen. It then spread over Syria and the Alpine Mountains, was observed on the highest summits of the Alps, and seen over a large part of North America.

This fog showed no traces whatever of humidity. Moreover, unlike most dry fogs due to fine dust in the air, it was not affected by heavy rains. It gave to the air a pale color, sometimes so dense as to prevent houses or trees from being seen at a distance of a thousand paces. The sun was seen only when it reached 12° above the horizon, and then, both on rising and setting, it had a blood-red color.

So far as the color of the sun is concerned, the same effect would be produced by the presence of finely divided volcanic dust in the air; but what gave to this fog characteristics that caused it to differ from other dry fogs was the disagreeable odor accompanying it. It has even been asserted that an acrid, sticky substance was deposited by it.

This fog caused great alarm all over the world, especially in the cities of Paris, Stockholm, Geneva, Rome, and Copenhagen, where it continued for a month or longer. During its prevalence there were often thunderstorms and powerful lightning flashes. Another circumstance that caused it to differ from ordinary dry fogs was the fact that, during its prevalence, a phosphoric gleam appeared in the air of sufficient brightness to permit the smallest print to be read at midnight.

In the opinion of some, a poisonous substance accompanied the fog; for a severe epidemic of catarrh followed. This, however, might have been caused by the breathing of any ordinary dust particles.

A similar dry fog, possibly also due to the presence of some extremely tenuous material from realms of space far outside atmosphere, was the fog of 1831. This fog spread over the entire Northern Hemisphere, and was attended by the same phosphoric light as the preceding fog. It gave to the sun's disc a curious blue or green color.

Besides dry fogs due to the presence in the atmosphere of matter that comes from outside the earth itself, are the dry fogs that can be directly traced to fine dust particles, generally of mineral origin, in the air. For example, during the great volcanic eruption of Krakatoa, in 1883, an eruption noted for its great power, volcanic dust was shot with such force from the crater that it is said to have reached many, many miles above the level of the sea. This height was so great that, although the coarser particles soon fell to the earth, the finer particles, carried by the wind, were spread over the entire earth, and, remaining suspended in the air for a year or longer, produced the remarkable sunsets that created so great an excitement over the whole world, especially among scientists.

I imagine that many, if not all of my readers who live in the temperate zone of the United States, know that beautiful time of the year called *Indian summer*, that occurs about the end of October and early in November. The air is then filled with dust particles, probably due to the presence of carbon obtained from the burning of forest or prairie regions in certain parts of the country. I do not mean that Indian summer is so pleasant because of the hazy condition of the atmosphere, but rather in spite of this hazy condition of the atmosphere.

The dry fog, known in Germany under the name of the *Höhrauch* (high smoke), is of a somewhat similar nature. The times of the year when it occurs, however, lack the pleasant climatic conditions that characterize Indian summer in North America; for, in Germany, it is regarded as a disagreeable phenomenon. The sky assumes a grayish tinge, which, at a certain height above the horizon, is attended by a brownish smoky haze. At the same time a peculiar smell of smoke makes the atmosphere as disagreeable to the sense of smell as its gray color is to the eye.

The cause of the Höhrauch is now generally thought to be the burning of peat areas in the heath districts of Northern Germany. In order, if possible, to win a somewhat larger harvest from the sterile peaty soil, the peat is set on fire in the spring. Since, as has been estimated, at least 60,000 acres are fired every year, consuming about 2,000,000,000 pounds of vegetable matter, you may form some idea of the amount of carbon particles thus thrown into the air, and, therefore, why the air acquires its disagreeable smoky color and odor.

CHAPTER XXII

NAVIGATION OF THE ATMOSPHERE

The desire to fly has existed among mankind from the earliest times. The gods, genii, and wizards of the ancient world were credited with the power of readily making their way through the air. Indeed, it was not so very long ago that, even in such a highly cultured centre as Boston, fairly intelligent people credited witches with the power of flying through the upper regions of the air with a no more complicated device than their far-famed broomsticks.

Some very marvellous stories have been told about people flying, or being carried through the air. As early as 625 B. C., it is said that a voyage through the air was actually accomplished by Kai Kaoos, King of Persia, the Cyaxares of the Greeks. An account of this aërial flight, taken from Persian and other Oriental tales found in a manuscript in the British Museum, is given by Bishop Wilkins of Chester as follows:

"To the king it became a matter of great concern how he might be enabled to ascend the heavens without wings; and for that purpose he consulted the astrologers, who presently suggested a way in which his desires might be successfully accomplished.

"They contrived to rob an eagle's nest of its young, which they reared with great care, supplying them with invigorating food.

"A frame of aloes-wood was then prepared, and at each of the four corners was fixed, perpendicularly, a javelin, surmounted on the points with the flesh of a goat. At each corner again one of the eagles was bound, and in the middle the king was seated with a goblet of wine before him. As soon as the eagles became hungry they endeavoured to get at the goat's flesh upon the javelins, and by flapping their wings, and flying upwards they quickly raised the throne from the ground. Hunger still pressing on them, and still being distant from their prey, they ascended higher and higher in the clouds, conveying the astonished king far beyond his own country. But, after a long and fruitless exertion, their strength failed them, and, unable to keep their way, the whole fabric came tumbling down from the sky, and fell upon a dreary solitude in the kingdom of China—where Kai Kaoos was left a prey to hunger, alone, and in utter despair."

No mention is made in this very improbable story as to why Kai Kaoos was not instantly killed.

The tale is almost rivalled by the story told in "Arabian Nights" of what happened to Sinbad the Sailor during his second voyage, in which he claimed to have been carried through the air by attaching himself to the foot of an immense bird called a roc.

It is stated by several writers that, some time about 365 B. C., Archytas of Tarentum invented a wonderful automaton in the shape of a pigeon that possessed the power of flying through the air.

But enough of these foolish stories. Let me now tell you something about what makes a balloon rise in the air. If you take a piece of cork in your hand and plunge it below the surface of water in a tub, and then open your hand, the cork will be pushed up through the water until it reaches the surface. Indeed, it will be pushed up so far that most of it will be raised above the level of the water.

Now, a balloon rises through the air for exactly the same reason that the cork rises through the water. When any solid body such as a cork is immersed in water, it displaces a volume of water exactly equal to its own volume. In doing this it loses a weight equal to the weight of the water it displaces. Since water is so much denser than cork, the weight thus lost by the cork, by reason of the water it displaces, is much greater than its own weight. In other words, the cork loses an amount of weight greater than its own, so that while in the water it may properly be said to weigh less than nothing.

It may seem strange for a cork or any other thing to weigh less than nothing, but I believe I can explain it to you. The weight of a body is due to the force of gravity pulling it downwards towards the earth's centre. What is generally called the *buoyancy* of water is due to a force pushing the cork directly upwards, or away from the earth's centre. When, therefore, I speak of the cork weighing less than nothing, I simply mean that the buoyancy, or upward pressure caused by the displacement of the water, is greater than the weight, or the downward pull caused by the attraction of the earth. The cork in the water is in a position similar to that of the rope employed in the *tug-of-war*. The side representing the weight of the cork is less strong than the side represented by the buoyancy of the water. There is, therefore, only one thing that can happen. The cork is pushed upward and rises rapidly through the water and, reaching the surface, is pushed out of the water into the air until it displaces an amount of water exactly equal to its own weight, when, the two forces being equal, equilibrium results and the cork quietly floats on the surface.

This power which liquids possess of buoying up bodies immersed in them was discovered by Archimedes, of Syracuse, one of the most learned of the early philosophers.

Archimedes had been requested by his royal master to find out whether a golden crown that had been made for him by his goldsmiths really contained all the gold he had given them, or whether they had mixed with it a quantity of the baser metals. The king imposed this condition, however, on Archimedes, that, in making this investigation, the crown was not to be destroyed.

This happened in 230 B. C. The problem gave Archimedes no little trouble. He was thinking about it in the street, and in the house, even when in bed. Indeed, for aught I know, he may even have dreamed about it. At any rate, one day, while in the bath and still thinking about this problem, he remembered that his body lost its weight when immersed in water, and suddenly saw how the king's problem could be solved. He became so elated at this great discovery, for it was a great discovery, that, without waiting to dress himself, he ran through the streets of the city shouting out in the Grecian tongue, "*εὑρέκα, εὕρεκα!*" which means, "I have found it. I have found it." Of course, the people in that city were both surprised and shocked that their great philosopher should act in so unseemly a manner. But, remembering that he was only a philosopher, and, therefore, probably did not know any better, they were willing to overlook the offense and therefore led him into a house and sent for his clothes.

The principle thus discovered by Archimedes may be stated as follows:

Bodies immersed in a liquid are buoyed up by a force equal to the weight of the liquid they displace; or, in other words, they lose a weight equal to the weight of the displaced liquid.

The principle of Archimedes applies to gases as well as to liquids. A body, when surrounded by air, loses a weight equal to the weight of the air it displaces. If a balloon, made of very great size, so as to displace a considerable bulk of air, and, moreover, made of light material, such as silk covered with varnish, so as to be rendered air-tight, be filled with some very light gas, its contained gas will weigh so much less than the displaced air that it will rise through the air, even when it has attached to it a fairly heavy basket loaded with people and their necessary food supplies and instruments. Like the cork the balloon will continue to rise until the weight of the air it displaces is exactly equal to its own weight, together with whatever is attached to it.

But our atmosphere is unlike water, in that it rapidly decreases in density as we rise above the surface of the earth. The balloon will only continue to rise in the air as long as the weight of the air it displaces is greater than its own weight. As it mounts higher in the air, the buoyancy of the air, or the force with which the balloon rises, rapidly decreases. As soon as it reaches air of such a density that the weight of the air it displaces is equal to its own weight and that of its load, it will cease to rise and will remain stationary in the air. If the aëronaut wishes to go still higher, it is only necessary for him to decrease the weight of the balloon by throwing something overboard. In order to prevent injury to people below, he uses ballast consisting of fine sand. When he wishes to descend, he opens a valve in the top of the balloon by pulling a cord, and lets out some of the gas; therefore the balloon shrinks, or decreases in size, and, as it displaces less air, it is held up by a smaller buoyant power.

The discovery of hydrogen gas by Cavendish placed a means in the hands of ingenious men to apply the principle of Archimedes to the production of balloons. It is a somewhat curious fact that, although Archimedes' great discovery was made at so early a date, it was not until shortly after the discovery of hydrogen that Dr. Black of Edinburgh made the announcement that a light bag filled with inflammable gas, as hydrogen was called at that time, would rise in the air. Hydrogen is a very light gas, being some fourteen and a half times lighter than air, and, therefore, about 11,160 times lighter than water. If, therefore, a very large bag were filled with this gas, the air it would displace would weigh very much more than the balloon and what was attached to it, so that such a balloon ought to be able to rise very high in the air.

Black does not appear to have actually built a hydrogen balloon. Lichtenberg, of Göttingen, was the first who succeeded in constructing a small balloon which actually rose in the air when filled with hydrogen. Tiberius Cavallo, an early philosopher, who wrote a fairly large book on "Aërostatics, or the Art of Flying," tried to make a balloon of very thin leather, but it weighed so much that, although filled with hydrogen, it refused to rise. In 1782 Cavallo by filling soap bubbles with hydrogen, succeeded in causing them to rise so rapidly that they struck the ceiling of his laboratory and burst.

1782 was a memorable year in the history of ballooning; for it was during this year that two Frenchmen, named Montgolfier, knowing that heated air is much less dense than cold air, conceived the idea of constructing hot-air balloons. When the air inside the balloons was caused to expand by heating, they would rise in the air by reason of the buoyancy of the colder, heavier air surrounding them.

The Montgolfier brothers sent up their first hot-air balloon on the 5th of June, 1783, from a place called Annonay, situated thirty-six miles from Lyons. The people who had been invited to see the demonstration, on entering the public square from which place the balloon was to be sent up, saw a ball 110 feet in diameter, with a wooden basket or frame attached to its base. This bag or balloon with its frame weighed 200 pounds. The inventors informed the assembled witnesses that, as soon as this bag was filled with a gas that they had discovered a simple way of making, it would rise to the clouds: for it appears that they wished to keep secret the fact that their balloon rose simply under the influence of heated air. As the air became heated, the balloon increased in size, swelling out and assuming a spherical form. It then endeavored to rise with such force that it required considerable strength to hold it in place. When, at a given signal, it was released, it rose in the air with great rapidity, and within ten minutes had reached the height of 6,000 feet. It drifted a little over a mile horizontally and then gently fell to the ground.

The Montgolfier experiment was so successful that Louis

XVI of France granted the brothers letters patent for their invention as a reward for their ingenuity.

The success of these experiments created intense surprise. As soon as the scientific men in Paris heard of it they determined to make a balloon which should be filled with inflammable gas or hydrogen, and at once started a public subscription for defraying the expense of its manufacture. A globular bag of varnished silk was soon constructed and was called a *ballon*, a word meaning a great ball. This was the first time this name was applied to such a device, our word balloon being derived from it.

The filling of the balloon with hydrogen began on the 23d of August, 1783. The people crowded around this great curiosity in such numbers that, to prevent the balloon from being injured by the crowd, it was secretly removed, on the 26th of August, to the Champ de Mars, a distance of two miles.

The balloon was liberated on the next day at 5 P. M. To the great surprise of the people it rose in two minutes to a height of 3,123 feet, when it entered a cloud. A heavy rain was falling at the time, but this did not prevent its rising. Of course, this only tended to increase the surprise.

It appears that the balloon, after remaining in the air for three-quarters of an hour, fell in a field on the outskirts of a village some fifteen miles from the Champ de Mars.

The following amusing account of the astonishment which its descent created in the minds of the inhabitants in this little village is quoted from "Astra Castra":

"For on first sight it is supposed by many to have come from another world; many flee; others, more sensible, think it a monstrous bird. After it has alighted, there is yet motion in it from the gas it still contains. A small crowd gains courage from numbers, and for an hour approaches by gradual steps, hoping meanwhile the monster will take flight. At length one bolder than the rest takes his gun, stalks carefully to within shot, fires, witnesses the monster shrink, gives a shout of triumph, and the crowd rushes in with flails and pitchforks. One tears what he thinks to be the skin, and causes a poisonous stench; again all retire. Shame, no doubt, now urges them on, and they tie the cause of alarm to a horse's tail, who gallops across the country, tearing it to shreds."

On the 19th of September, 1783, Montgolfier sent up a balloon at Versailles in the presence of the King, Queen, and court, and a great multitude of people of every rank. The ascension was noted for the fact that this balloon was the first to take living things on an aërial voyage. It was not, however, one of the human family that had the honor of first moving through the air; for, in the cage of the balloon, a sheep, a rooster, and a duck were placed.

The balloon rose to the height of 1,440 feet, and was carried by the wind to a distance of about two miles from Versailles, where it descended after remaining in the air for only eight minutes. The animals landed safely with the exception of the rooster who had his right wing somewhat injured, while the duck had been injured by a kick from the sheep. The latter had evidently not been inconvenienced, since it was feeding when the balloon reached the ground.

CHAPTER XXIII

EXPLORATIONS OF THE HIGHER REGIONS OF THE ATMOSPHERE

You have probably heard the story of Daedalus, the Greek sculptor, who invented wings for flying like a bird. His son, Icarus, who believed sufficiently in his father's invention to use these wings, was drowned in the Icarian Sea. It was claimed that Icarus succeeded in mounting in the air, and, in his pride at thus being able to leave the earth, he flew towards the sun, the heat of which melted the wax his father had employed for fastening the feathers in his wings so that he fell to the earth where he found a watery grave.

Of course, the story of Icarus is entirely imaginary. In more recent years various unsuccessful efforts have been made by men to provide themselves with wings and actually fly through the air. All these efforts have failed, because man is not sufficiently strong to raise himself in the air by his own exertions.

Among the many efforts made in this direction, I will mention only a few. In 1678 Besnier, a French locksmith, constructed a flying-machine consisting of four wings, or flaps, attached to the ends of levers resting on his shoulders, and driven by the alternate motions of the hands and feet. Besnier was never able to leave the ground by the use of this machine, but, by going to the edge of a precipice, and throwing himself from it into the air, he could descend in a diagonal direction, and even cross a river that flowed near the foot.

A somewhat similar device, employing only two wings, was made by a watchmaker in Vienna named Jacob Dagen.

But, coming now to balloons that actually carried people through the air, it appears that the honor of being the first to make an ascent in a balloon is due to Pilâtre de Rozier, a young and talented French physicist. After the safe aërial voyage of the rooster, duck, and sheep sent up by Montgolfier, as related in the last chapter, it was determined to send up a balloon large enough to carry two men with it into the air. This was done on the 15th day of October, 1783, by means of a *Montgolfier*, or hot-air balloon, sent up from Paris.

There was naturally some little hesitation on the part of any one to risk his life in this experiment. The king and his court, however, wishing to have the experiment tried, decreed that two men under sentence of death should make the ascent.

On hearing this decree, Pilâtre de Rozier exclaimed to his friends: "What! shall vile criminals be given the honor of being the first to be carried through the air? No, no; that will never do."

These remarks being noised through the city, at length reached the court, and the king, at the earnest entreaties of the Marquise d'Arlandes, who agreed to accompany de Rozier, gave permission to the young physicist to make the attempt.

This ascension was made on the 15th of October, 1783. The fire was lighted in a gallery placed below the open mouth of the balloon and the balloon was rapidly inflated by the hot air. It carried M. de Rozier to a considerable height. After remaining in the air for a short time, he descended in safety. In this first ascension Pilâtre de Rozier was alone.

These experiments were so successful that a prize of 600 livres was given to the Montgolfier brothers for their invention.

But I must now give you a brief description of the first aërial voyage made by a man in a ballon filled with inflammable air, or hydrogen gas. The success of the first hydrogen balloon, referred to in the preceding chapter as having been sent up from the Champ de Mars, as well as Pilâtre de Rozier's successful ascension, led to an attempt being made in Paris to construct a hydrogen balloon large enough to carry two men. A subscription was started in Paris, and the balloon, properly inflated with gas, was freed from the ropes that held it to the ground on December 1st, 1783.

The balloon was made of silk covered with varnish so as to render it gas-tight. It was spherical in shape, and measured twenty-seven and a half feet in diameter. It was constructed by the Roberts brothers, French mechanics. A car, or boat, was swung below the balloon by ropes attached to a network of cords passing over the top. In order to prevent the bursting of the balloon by the expansion of the hydrogen, on the relief of the atmospheric pressure in the higher regions of the air, a valve was provided in the top of the balloon which could be opened by pulling a rope, so as to let out some of the inflammable gas and thus reduce the pressure. There was great excitement in the city. The crowd was so great that it was necessary to place soldiers to preserve order.

The two men, who were given the honor of making this first ascension in a hydrogen balloon, were one of the Roberts brothers and Professor Charles, Professor of Physics, in Paris, who had successfully sent up a hydrogen balloon in 1782.

When the balloon reached a height of 600 yards, the two aërial navigators indicated their safety by frequently waving two pennants. The balloon remained stationary at this height for a short time, when it was carried in a horizontal direction to the N.N.W. across the Seine and over several towns and villages in the neighborhood, where it caused great astonishment. After an hour and three-quarters, it descended in a field about twenty-seven miles from Paris. The balloon had travelled at the rate of about fifteen miles an hour, with no inconvenience to its passengers saving only the sudden changes of temperature to which they were exposed.

When the balloon reached the ground, it still contained considerable gas, so that Professor Charles determined to ascend once more by lightening the balloon. He therefore requested Mr. Roberts to get out, thus decreasing the weight by 130 pounds. It had been intended to replace most of this weight by ballast, but, as it was nearly sunset, and Professor Charles did not wish to lose any more time, he gave the signal to the peasants to let the machine go.

At this time there were two kinds of balloons that were capable of carrying aëronauts through the upper realms of the air: the *hot-air balloon* of Montgolfier and the *gas balloon* of Charles. I would say, in passing, that Professor Charles did much towards the improvement of the balloon. It was he who invented the valve for allowing the gas to escape, and thus permit a slow and gradual descent of the balloon, as well as prevent its bursting when under the relief of atmospheric pressure in the upper regions of the air. It was he who also arranged the basket, or car, for the aëronaut to sit in, with the ropes to support it. He, too, suggested the use of ballast to regulate the height of the ascent, as well as the varnish that renders the silk impermeable and so prevents the loss of gas. It is not surprising, therefore, that in France gas balloons are generally known as *Charliers*, just as the hot-air balloons are called *Montgolfiers*.

Pilâtre de Rozier, the first aëronaut, made a number of successful balloon ascensions. He was not only the first to soar through the air by the aid of a balloon, but he was also the first to be killed during an ascension. An Englishman by the name of Blanchard had successfully crossed the Straits of Dover on the 7th of January, 1785, on a clear frosty morning when a mild breeze was blowing from England to France. When Pilâtre de Rozier heard of this successful voyage, he determined to cross the Channel in the opposite direction, from France to England, and, accompanied by a French gentleman named Romaine, left Boulogne on the 15th of June, 1785.

For this voyage Pilâtre de Rozier conceived the idea of making his balloon of a type that united the system of Montgolfier and that of Charles, and was called a *Charlo-Montgolfier balloon,* in which the balloon was inflated by hydrogen gas, but a small fire balloon was also used by the heat of which Rozier hoped to alter the density of the hydrogen gas as occasion might demand. The inventor was correct in his theory, but was unfortunate in its application. When the balloon rose in the air and distended its sides so as to threaten to burst, some of the inflammable gas escaped from the tube that formed the neck of the balloon. It reached the flame of the hot-air furnace and set fire to the balloon, which was partly consumed in the air, and the unfortunate aëronauts were dashed on the rocks between Calais and Boulogne. Pilâtre was almost instantly killed and all his bones broken. Romaine still showed some signs of life, but died soon afterwards.

FIG. 46. THE PARACHUTE

It was largely owing to this accident that the *parachute* was invented. Its general appearance is represented in Fig. 46. When it becomes necessary for an aëronaut to abandon his balloon, he safely descends in the parachute. The parachute is formed of strong cloth, and, when extended, resembles a huge umbrella. In the place of the whalebone ribs of an umbrella are cords that hold a small basket in which the aëronaut sits. In falling, the parachute would assume a rapid whirling motion, on the principle of the reaction water wheel, were the air it contains permitted to escape from its circumference. To prevent this a hole is made at the top, so as to permit the air to escape centrally.

There are cases on record where balloons have accidentally burst, and, thus losing their gas, have begun to fall with frightful velocity. Soon, however, the huge folds of silk that form the walls of the balloon have assumed the form of a parachute, so that the aëronaut has reached the ground in safety.

Some of the most remarkable balloon ascensions ever made were those by Messrs. Glaisher and Coxwell, from Wolverhampton, England. These ascensions were undertaken at the request of the British Association for the express purpose of exploring the higher regions of the atmosphere, especially as regards the temperature and their amount of moisture at different elevations.

During one of these ascensions, namely, that on September 5th, 1862, the balloon reached an extraordinary height, thus permitting its occupants, Messrs. Glaisher and Coxwell, to rise far above the summits of the highest mountains. As this balloon was especially equipped with apparatus provided for making scientific observations concerning the temperature, moisture, and other peculiarities of the higher regions of the air, the information obtained during this ascent was of great value to science. I will, therefore, give you the particulars of this remarkable ascent somewhat in detail.

The balloon was cut loose in the early afternoon. The temperature of the air at the surface was 59° F., and the dew-point 50°. The balloon rose rapidly. When at a height of one mile above the sea level, the temperature was 41° F., and the dew-point 38°. The balloon then passed through a cloud about 1,100 feet in thickness, when the temperature of the air fell to 36.5° F., the dew-point remaining the same. At the height of two miles above the sea, the temperature of the air had fallen to the freezing-point and the dew-point to 26°. At the height of three miles, the temperature was 18° F., and the dew-point 13°. At the height of four miles, the temperature was 8° F., and the dew-point —15°. At five miles, the thermometer indicated 2° F. below zero, and no dew was observed on the hygrometer (Regnault's), when cooled down to —30°.

The balloon was now five miles above the level of the sea. Glaisher so far had experienced no difficulty in breathing, because he had not been making any exertions. His companion, however, Mr. Coxwell, was breathing with difficulty. When the barometer indicated an elevation of 29,000 feet, or nearly six miles, Glaisher was so affected by the low pressure that he was unable to move his arms, and, while looking at the barometer, his head fell on his right shoulder, and he fell backward with his head resting against the back of the car. This observation of 29,000 feet was the last he made. Mr. Coxwell, though suffering at the first more than Mr. Glaisher, was still conscious.

You may inquire how it was that the aëronauts succeeded in again reaching the ground. It appears that Glaisher's companion, Mr. Coxwell, before losing consciousness, had seized the cord communicating with the valve in his teeth, for his hands were so frozen that he could not firmly hold the ring. By dipping his head two or three times, he opened the valve so that the balloon took a decided motion downwards. It is possible, too, that on his finally fainting, with his teeth still grasping the valve rope, the valve was opened by the weight of his body.

There was in the balloon a very delicate minimum thermometer, a device for recording the lowest temperature to which the balloon would be exposed. The recorded temperature indicated a height between 36,000 and 37,000 feet. Again, Mr. Coxwell, while endeavoring to seize the ring connected with the valve rope, had noticed that the centre of the aneroid barometer, its blue pointer, and a rope attached to the car, were all in the same straight line. This would give a reading of seven inches which, like the minimum thermometer, would indicate an elevation of about seven miles.

The conclusions concerning the upper regions of the atmosphere that were drawn from these remarkable ascensions were as follows:

"1. That the temperature of the air does not decrease uniformly with increase of elevation above the earth's surface; and, consequently, the theory of a decline of temperature of 1° F. in every 300 feet must be abandoned. In some cases, with a clear sky, the decline of 1° F. has taken place within 100 feet of the earth; and, for a like decrease of temperature, it is necessary to pass through more than 1,000 feet at heights exceeding five miles.

"The determination of the decrease of temperature with elevation and its law, is most important; and the balloon is the only means by which this element can be determined; but very many more observations are, however, necessary.

"2. That the humidity of the air decreases with height in a wonderfully decreasing ratio, till at heights exceeding five miles the amount of aqueous vapor in the atmosphere is very small indeed.

"3. That an aneroid barometer reads correctly to the first place, and probably to the second place of decimals, to a pressure as low as seven inches."

The balloon is almost the only medium for the study of cloud forms in the upper regions of the air. From the surface of the earth we can see only the lower portions or the sides of the clouds; but when the balloon rises above the clouds, we can see all of their upper surfaces.

If a balloon ascension takes place during a very cloudy day, when the entire sky is overcast with thick cloud masses, a curious, and, at the same time, a beautiful sight is had as the balloon passes through the cloud, especially if the ascension is made shortly before sunset.

The possibility of crossing the ocean with a balloon was believed in to such an extent in 1840, that a Mr. Charles Green announced his readiness to attempt to cross the Atlantic in a balloon especially built for the purpose, provided a sufficient sum could be obtained.

I regret that want of space will prevent my telling you of some of the attempts that have been made to overcome obstacles at the surface by moving through the air in balloons, especially during wars. I must, however, tell you something about Andrée.

Solomon Auguste Andrée, a Swedish aëronaut, conceived the bold idea of reaching the North Pole by the aid of a balloon. Accompanied by Dr. S. T. Strindberg and Herr Fraenckell, he left Dane's Island, on the coast of Spitzbergen, on the 11th of July, 1897.

Andrée's balloon had a capacity of 170,000 cubic feet of gas, its diameter being sixty-four and a half feet. Assuming that its speed would average from ten to twelve miles an hour, the balloon should have been able to carry these men to the pole in six days, provided, of course, the wind blew from the right direction.

Poor Andrée and his companions undoubtedly perished; for, although two days after their departure from Spitzbergen a message was received by a carrier pigeon, stating that the balloon had reached lat. 82.2° N., and long. 15.5° E., and was still making satisfactory progress, yet neither the balloon nor its occupants were ever heard from again.

During the last ten years many improvements have been made in balloons. The most important of these have been in their construction, whereby their motion through the air is to a great extent independent of the direction of the air currents in which they may be immersed. Of course, in order to do this, the balloon must be provided with motive power that is independent of the action of the winds. This power can be obtained either by powerful electric motors, driven by electric storage batteries placed in the balloon, or by a gas engine driven by gasoline or similar material. The latter machines appear to have produced the best results, since by their use a greater amount of power can be obtained with the least weight of machinery.

Balloons that are capable of moving through the air in directions irrespective of the winds, are generally known as *dirigible balloons.* Some of the distinguished men who have worked in this direction are Gaston Tissandier, who was the first to partially solve this problem. At a latter date, Santos-Dumont, of Paris, constructed a dirigible balloon by which in November, 1899, he was able to circle around the great Eiffel Tower.

Inasmuch as a pear-shaped balloon possesses the disagreeable feature of spinning, or rotating like a top, different shapes have been given to balloons. Cigar-shaped balloons have been frequently employed as dirigible balloons.

CHAPTER XXIV

OPTICAL PHENOMENA OF THE ATMOSPHERE

That our atmosphere is transparent, is evident from the possibility of distinctly seeing distant objects. But the degree of this transparency differs markedly from time to time. The presence of even an exceedingly small quantity of fog particles in the air so decreases its transparency as to very greatly limit the distance at which objects are visible. In a similar manner, especially after a long dry spell in summer, the air may be so filled with minute particles of dust as to cause a haze that greatly limits our vision.

The atmosphere, together with the different objects on the earth's surface, are frequently spoken of as the "face of Nature." In this sense, Nature, like some of her children, often sadly needs to have her face washed. This is practically done whenever it rains.

You have doubtless noticed how much clearer the distant landscape is immediately after a rain, followed by clearing weather and a blue sky. This is because the rain has washed most of the dust and dirt out of the air.

The transparency of the atmosphere differs markedly with its height. If you have ever ascended a high mountain, or, indeed, for the matter of that, a fairly high hill, you may have noticed how much clearer during certain days the air seems than during other days. As you look towards a distant range of mountains, you are able to see with much greater clearness the details of different objects on its higher levels, than you can in the valley below. This is because there are fewer dust particles in the higher air than in the lower air of the valleys.

The imperfect transparency of the atmosphere is more noticeable as the length of the path through which the light passes is increased. It is for this reason that we can look directly at the sun, when it is nearly sinking in the west, or shortly after it has risen.

The air is far purer and, therefore, more generally transparent in tropical and polar regions than in the temperate regions. In the clear, pure air of some of the tropical Andes, distant objects can be seen distinctly at distances of from forty to fifty miles under favorable conditions when there has been no wind for some time.

It is especially in tropical deserts under similar conditions that the clear, blue, dry air is so transparent.

The cold dry air of the Arctic zone is also wonderfully transparent. Under favorable circumstances distant objects can be seen with marked clearness. The rigging of a ship at a distance of twenty-five or thirty miles can be seen with an ordinary glass when it is just coming up above the horizon, while the summits of mountains are distinctly visible at distances varying from sixty to a hundred miles.

We are so accustomed to estimate the distance of an object by the clearness with which we can distinguish its details, that it is necessary to make a correction for the clear air of tropical deserts, the higher levels of mountans, or the different parts of the Arctic zone. It is by no means an unusual thing, to those who have had little or no experience with unusualiy transparent air, to make ridiculous mistakes in estimating the distance of some clearly distinguishable object; for, often what appears to be only a few miles distant, is in reality very much farther away.

Let us see if we can understand the cause of the blue color of the sky, as well as the glorious tints of the sunrise and the sunset. You may be surprised to learn that the color of an object is not a property of the object itself, but of the light that falls upon it. Ordinary sunlight, and, for the matter of that, the light of nearly all artificial illuminants, does not consist of a single color, but of a great number of colors. When the different rays are permitted to act alone on the eye, each is capable of producing its characteristic effect. It may be a red, an orange, a blue, or some other color. The light of the sun appears what we call *white,* because all of these colors act simultaneously on the eye. If a narrow band of sunlight be permitted to enter a dark room through an opening in a shutter, it will continue in the same direction and will fall on the floor. If, however, it be passed through a prism, it will be turned out of its course both on entering, as well as on leaving the prism. During its passage through the prism, the different colored rays that are present in sunlight are turned out of their course to such an extent that, when they are received on a screen

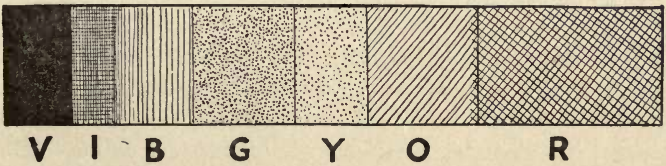


FIG. 47. SPECTRUM

placed on the opposite wall, they produce a brightly colored band called a *spectrum,* or band of rainbow colors. For convenience these different colors are arranged in groups, as shown in Fig. 47, where they are represented by their initial letters, V I B G Y O R; or into violet, indigo, blue, green, yellow, orange, and red. As you will see from an examination of light passing through a prism, the violet rays are the most, and the red rays are the least turned out of their course; or, in other words, the violet rays are the most refrangible and the red the least refrangible; so that the colored band, or spectrum, will be arranged with the violet at the top of the spectrum and the red at the bottom, with the other colors occupying intermediate positions.

The statement that the color of a body is due to the color of the light which falls on it, and not to the body itself, is the same as saying that all bodies are devoid of color in the absence of light. A piece of red flannel is red because, when sunlight falls on it, all the colors of the spectrum but the reds are absorbed, or converted into heat, the red lights only being given off. So, too, the blue color of a flower is caused by all the colors but the blues being absorbed.

Many of the optical phenomena of the atmosphere are very difficult to understand, unless considerable time is given to their explanation. I feel sure, however, that they can be made plain, and in the "Wonder Book on Light," I will explain in full the principles upon which these phenomena depend. Here, however, I would say briefly that practically all the optical phenomena of the air are due to changes in the direction, brightness, or color of the rays of light while passing through the air, through fog or cloud particles in the air, through crystals of ice or snow, or while passing close to the edges of ice crystals or pieces of floating dust.

For example: the reflection of the rays of light coming from objects may cause them to be seen out of their true position, and to appear turned around from right to left, or upside down. By *refraction*, that is, by the change in the direction of light in passing from air into water or glass, or from air or glass into water, they may appear out of their true position, or may seem larger or smaller than they would ordinarily appear; or the light may be so turned out of its course by reflection as to make it possible to see objects that would otherwise be hidden by opaque bodies; or the dispersion of light from bodies may cause them to appear to be surrounded by fringes of rainbow colors.

The gorgeous colors seen in the sky at sunrise and sunset are caused by the sunlight being dispersed, or separated into its prismatic colors, while passing through the clouds or masses of vapor near the horizon. The colors that are least turned out of their course, such as the yellows, the oranges, and the reds, alone pass through and, falling on the clouds, light up the western sky.

I will not attempt to describe to you the beauties of the sunset. I would much prefer that you see them for yourselves; for they hardly ever twice appear the same. This is due both to the varying forms of the clouds, and to their different heights above the earth's surface; for, the very high clouds are able to catch the colored rays of the sun, which would otherwise pass at too great heights above the earth's surface to enter our eyes, thus producing a combination with the various tints of red, yellow, or orange, with patches of green or violet. So, too, a glow also appears over the western sky, due to its general illumination from colored clouds.

In the case of the ocean, or other large water areas, the reflection of the colored light from the sky itself, as well as the mirrored image of the sunset tints, produces an appearance of marvellous splendor that must be seen to be realized.

Let us now see if we can understand the cause of the beautiful blue color of the sky. This is produced in an entirely different manner from that of the colors of the sunrise or sunset; and, curiously enough, is due to the presence in the air of minute particles, that are, in themselves, quite devoid of color. Without going into a full explanation of this phenomenon, I would say that the light is transmitted from luminous bodies to our eyes by means of waves, in a medium called the *luminiferous ether*. All light waves are exceedingly small. So small, indeed, that in the case of the longest of these rays, the reds, over 39,000 could be placed edge to edge in the length of an inch, while in the violet, nearly 60,000 could be placed in the same space.

Now, the blue color of the sky is due to the reflection of the different waves of sunlight from the surfaces of exceedingly minute particles of water, or other matter, that are floating in the atmosphere. It is probable that the color of the sky is due mainly to the presence of minute particles of water. When these particles are exceedingly small, only the blue or the violet rays can be reflected from them; and as blue is the characteristic color of the sky, it is believed that its light is produced in this manner.

It was Professor Tyndall who first pointed out the cause of the blue color of the sky. If our atmosphere were perfectly transparent, it would appear absolutely black. Tyndall has shown that, when certain extremely thin or attenuated vapors are either decomposed, or condensed into fine particles by any suitable cause, as the clouds begin to form, or when the liquid particles have their least size, they are invariably of a blue color. This cloud is not visible in ordinary daylight, but must be surrounded by darkness. It must have no other illumination than that of the beam of light. As the cloud particles increase in number and size, the color gradually acquires a white tinge, until at last the particles look like an ordinary cloud.

Any collection of extremely small particles of matter when floating in the air, if viewed on a fairly black background, will appear of a bluish color. For example: the smoke of a fire, when seen against a dense piece of woods for a background, appears of a bluish color. So, too, the smoke from a cigarette or pipe has also a bluish color when examined against a sufficiently dark background.

Many resinous substances, when dissolved in alcohol, are practically devoid of color. If a drop of such a solution is permitted to fall into a large, clear, glass vessel, filled with pure, transparent water, the resinous matters are separated in the form of numerous particles that have a distinct blue color, when illumined by the passage of a strong beam of sunlight through the water. In order to obtain the best results, it is necessary that exceedingly small quantities of the dissolved resins be thrown into the water. Otherwise, the cloud of floating particles will assume a milky white or opalescent appearance; or will appear of a milky whitish color by reflected light and a reddish tinge by transmitted light.

Since eau-de-Cologne consists largely of odoriferous resins, gums, or oily extracts dissolved in alcohol, a drop of Cologne thrown into water will produce a bluish cloud from the great number of very minute suspended particles thrown down from the dissolved resins.

The *rainbow*, another optical phenomenon of the atmosphere, is caused by the dispersion of the sunlight by refraction as it passes through falling drops of rain. The rays of light entering the drops are reflected from the surfaces furthest from the sun, and pass out of the drops separated into the prismatic colors. Rainbows are seen when the observer stands with his back to the sun, and are largest when the sun has nearly set.

The phenomena of the rainbow, however, are far more complex than would appear from the above explanation. In some cases the rays of light enter the drops near the top and are reflected once from the further side of the drop, and, entering the eye of the observer form the *ordinary rainbow*, or, as it is sometimes called, a *primary rainbow*. Other drops, however, are so situated with respect to the eye of the observer that the rays of light entering at the lower portion of the drop turned towards the sun are twice reflected from the back of the drop, and enter the eye of the observer, producing another rainbow called a *secondary rainbow*, which is seen above the primary bow. The arrangement of the prismatic colors is different in the two bows. In the primary bow, the red is at the top of the arch and the violet below, while in the secondary bow the violet is above and the red below. Since a greater amount of light is lost by double reflection, the secondary bow is not as bright as the primary bow.

Although each raindrop is capable of producing all the colors of the prismatic spectrum, yet only a single set of colors that pass out of the drop at a particular angle are capable of affecting the eye of an observer. In the great number of raindrops present in a storm, only those from which these particular rays of light emerge at this angle can affect the eye of the same observer; he will see an arc or bow of this colored light, the diameter of which will vary with the position of the sun. Other drops produce the other colors of the spectrum, so that the observer sees a colored band, or bow, that spans the heavens in the well-known shape of the rainbow.

No two people have ever seen exactly the same rainbow. I mean this in a strictly scientific sense, since no two people

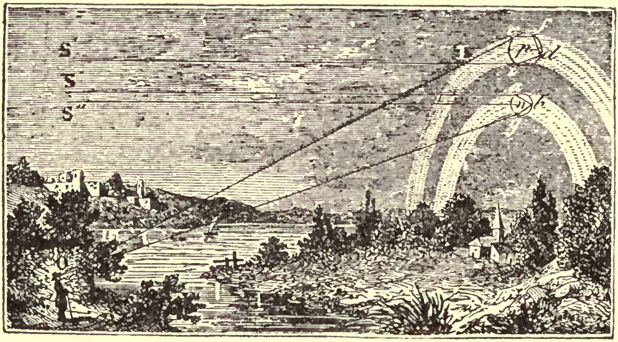


Fig. 48. Manner in Which the Colors of the Rainbow Are Produced

can utilize exactly the same rays of light that come from the same raindrop. You will understand, of course, that practically the same rainbow is seen simultaneously by thousands of people not far apart from one another, who are observing the same portion of the heavens.

The manner in which the different colors are produced by the passage of the rays of light through the raindrops, after both a single and double reflection, will be understood by a study of Fig. 48.

The rainbow, as you know, was appointed by God as a sign of His promise that the earth should never again be destroyed by a flood. You must not suppose by this that there was never a rainbow before that time; for, rainbows must have existed before man was created; but God chose this very beautiful phenomenon as a token of the covenant He had made with the children of men.

The ancients, who attributed all the phenomena of nature to the gods, called the rainbow Iris.

Although during a storm raindrops are constantly falling, so that the rays of light that are utilized by any observer are constantly changing, yet their places are so rapidly taken by others that the phenomenon appears uninterrupted, and continues as long as the rain continues to fall.

The rays of the moon are also capable of producing similar phenomena called *lunar rainbows*. The bows thus formed differ in no respect from ordinary rainbows, except that they are much less brilliant owing to the feebler illumination.

Sometimes a small rainbow can be seen at certain times of the day in the neighborhood of waterfalls. These bows are due to the passage of the sunlight through drops of water or spray at the foot of the cataract.

On the 15th of September, 1851, something occurred at Geneva that greatly terrified the uneducated people; for, besides the bright everyday sun, four additional suns were seen in the sky. This phenomenon was so astonishing to them that they feared the Day of Judgment was coming, and that the sun was multiplying himself in order to set the earth on fire. This phenomenon can be so thoroughly explained that it need have occasioned no alarm.

I will not attempt an explanation here, since the causes of this optical phenomenon are exceedingly complicated. I will merely say, however, that you can easily see a halo at any time around a source of light by sprinkling over the surface of a clean, dry plate of glass some lycopodium powder. Lycopodium is a resinous powder that consists of the minute seeds of various club mosses. It is frequently placed inside pill boxes to keep the pills from sticking together, so that if you want to try this experiment and have none of this material on hand, I am sure that the nearest druggist will sell you some for a few pennies. Dusting a very small quantity of the powder over the surface of a clean, glass plate, and looking at a distant source of light with the eye placed close back of the smooth portion of the glass, the light will be seen surrounded by a number of haloes or rings of light.

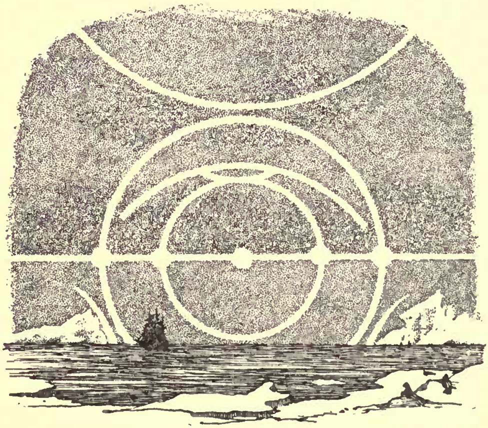


Fig. 49. Arctic Halo

Haloes are the names given to rings that are seen surrounding the sun. These rings are sometimes of prismatic colors, although they often consist of apparently white light. Briefly speaking, they are caused by the presence of small crystals of ice or snow in the air. They assume various shapes.

Fig. 49 shows a halo as seen in the Arctic regions. Sometimes luminous bands, or rings, cross these circles. When this occurs, a very bright luminous spot is produced. Since these spots bear some resemblance to the sun itself, they are called *parhelia*, or *mock suns*. In the above figure four mock suns are visible, two on each side of the sun where the light horizontal band crosses the two circles around the sun. The phenomenon referred to as occurring near Geneva in 1851, was of this character.

Similar luminous circles, called *coronæ*, are frequently seen around the moon. They differ practically in no respect from *solar haloes*, and, indeed, are called *lunar haloes*.

It was at one time a common belief that a huge demon walked around on the solitary mountain ranges in a certain district of the Hartz Mountains, a moderately high mountain chain that extends between the Weser and the Elbe, south of Brunswick, Germany. This demon, known as the *Spectre of the Brocken*, was said to take the shape of a wild man of huge stature, carrying, in one hand, a pine tree that he had torn up by the roots.

Prior to 1797, the actual existence of this demon was believed in by the miners, and other ignorant people of the districts; and many a story was told by their fathers at the firesides of their seeing him stalking in giant strides over the mountain tops.

Suspecting that the so-called Spectre of the Brocken was merely the magnified shadow of the person who saw it, a traveller named Haue climbed to the top of the Hartz Mountains in order to test the correctness of his suspicions. Finally, after no less than thirty fruitless efforts, he had the good fortune, on the 23d of May, 1797, to behold it. It was shortly after sunrise, on a day when the weather was fine and the west wind had been collecting transparent vapors in front of the mountain. About fifteen minutes after sunrise Haue saw in the west a human figure of gigantic size. At that moment, the gust of wind threatening to blow away his hat, he quickly raised his hand to stop it. The huge figure did the same thing. Convinced now that his suspicion was correct, he made a stooping motion, when the image repeated it. He then continued making a number of curious gestures, all of which were repeated by the figure. Calling a companion to observe this phenomenon, he found, when they reached the spot, that it had disappeared. Shortly afterwards, however, two gigantic figures again appeared. The much feared Spectre of the Brocken had at last been unearthed, and proved to be nothing but the shadow of the observer that the rays of the rising sun threw in a magnified size on the screen of clouds in the west.

Professor Tyndall describes the Spectre of the Brocken as follows:

"Proceeding along the mountain to the Furca, we found the valley on the further side of the pass filled with fog, which rose like a wall high above the region of actual shadow. Once, on turning a corner, an exclamation of surprise burst simultaneously from my companion and myself. Before each of us, and against the wall of fog, stood a spectral image of a man of colossal dimensions, dark as a whole, but bounded by a colored outline. We stretched forth our arms; the spectres did the same. We raised our alpenstocks; the spectres also flourished their batons. All our actions were imitated by these ringed and gigantic shadows. We had, in fact, the Spirit of the Brocken before us in perfection."

There is another variety of spectre seen on the clouds known as the *Ulloa circle*, from the name of its first observer. In this phenomenon the observer sees, not his shadow, but rather his image reflected in the air from ice particles, as in a huge mirror, in the centre of several rainbows of different colors. These bows are seen in a vertical position and move with the movements of the person whose image they surround as a kind of glory. Sometimes the bows are not colored, but consist of ordinary white light. For this reason the name *white rainbow* is sometimes employed instead of the "Ulloa circle." As in the case of the rainbow, although a number of people may see their own images surrounded by the luminous circles, none of them see the images of the others.

The general appearance of the Ulloa circle is represented in Fig. 50.

The position of the image of an object is determined by the direction in which the rays of light enter the eye of the observer; and this is true whether those rays enter his eyes directly, or after they have been thrown off from some suitable reflecting surface.

There are a number of exceedingly curious optical phenomena that are due to a change in the apparent position, or dimensions of an object. These phenomena are known under the general term *mirage*.

It will be easier to understand the cause of the mirage by taking one of the simplest cases, namely, that known as *looming*. At sea, when a distant ship comes into view, its upper masts are first seen just above the horizon. As the ship draws near, the lower parts of the mast, and finally the whole ship is seen. This is due to the spherical shape of the earth; for, ordinarily, light coming from distant objects, passes through the air in perfectly straight lines. To enable an observer to see a distant object, it is necessary that the light shall enter his eyes. If, therefore, a ship, or distant object, is too far below the horizon, although the rays of light passing from the object in all directions pass above the horizon, and so through the air, they pass above the eyes of the observer, and since they fail to enter the eye, the object remains invisible.

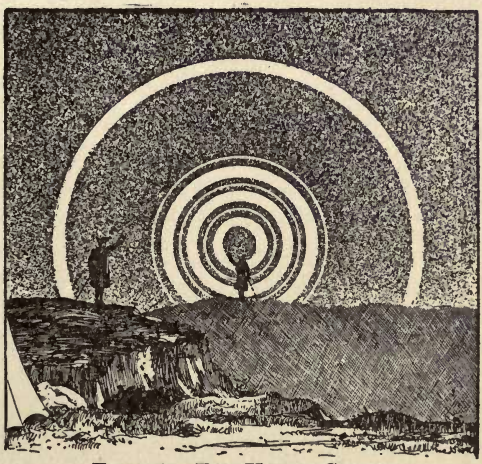


FIG. 50. THE ULLOA CIRCLE

Sometimes, however, the strata of air over the ocean either increase rapidly in density from the surface upward, or the reverse. In other words, there is a gradual increase or decrease of temperature from the surface upwards. Now, in the first case, the rays of light would be so bent out of their course as to curve sufficiently, as they pass the edge of the horizon, to enter the eye of the observer; so that objects are raised, or brought into view, although they might be so far below the horizon as to be completely invisible. This phenomenon is called *looming*.

Some curious stories are told concerning the remarkable effects of looming. On the 26th of July, 1798, there was suddenly seen in the air over a part of the coast of England, a mirage that was afterwards recognized as being a part of the French coast that was at a distance of from forty to fifty miles. It was, therefore, too far below the horizon to be seen directly, but, under the influence of the looming, the rays of light from the object were sufficiently bent to enter the observer's eyes and so the object became visible.

A report was once spread at Malta that a new island had risen from the sea in the channel, at a distance of four or six leagues. The different objects on this island were so clearly visible to the unaided eye, that several ships in the harbor left for the purpose of taking formal possession of the new land in the name of their respective countries; for, not only could the island be seen, but also a high elevation near its centre. This was afterwards proven to be a portion of the coast of Sicily including Mt. Etna. Under ordinary circumstances, Sicily is too distant to be visible; but it had been raised above the horizon by this extraordinary bending of the rays of light.

There is a variety of mirage that is frequently seen in the Straits of Messina, on the coast of Calabria, that is known as the *Fata Morgana*.

During this phenomenon a person standing on a hill with his back to the sun, on looking towards the sea, can frequently see with fair distinctness castles with their lofty towers, magnificent palaces, with their balconies and windows, trees and herds, flocks feeding on the plains, and even, it is said, armies of men on foot and on horseback, rapidly passing in a never-ending stream on the surface of the water. They appear to be resting on the surface of the water, and to add to the beauty and strangeness of this scene, when the air is misty or hazy, the objects appear fringed with the colors of the rainbow.

It is no wonder that ignorant pople, especially those who lived many years ago, firmly believed that these images resulted from the enchantments of a fairy called Morgana. It is now known, however, that there is nothing magical about them, but that they are simply due to a remarkable case of looming, by which the distant town of Messina, on the opposite coast of the Straits, has been brought into view.

There is a variety of mirage, that is especially apt to occur in the heated air of the desert. Here a distant oasis, too far below the horizon, however, to be directly visible, is brought into view, by looming, and appears as if surrounded by a sheet of water, such as a lake, in which can be seen, as if reflected in the waters of the lake, the inverted images of the trees.

It must, indeed, be very tantalizing to the tired travellers when greatly suffering from want of water, to find, on reaching the place, that the water has disappeared. Hence, this deceptive appearance has received very suggestive names in different parts of the world. For instance, in some places it is called the *Sea of the Devil.* In other places, the phenomenon is spoken of as *The Mysterious Water.* This species of mirage is believed to be due to a rapid increase of the temperature of the air downward to within a few inches of the surface. The result is an upward bending of the rays and a reflection of light so as to cause an apparent inversion of the image. The appearance of the water surface is apparently due to a flickering movement of reflected images, due to the currents set up between the hotter and the colder air. There thus result those peculiar appearances that closely resemble the rippling of waters on a lake. Then again, since the sky is sometimes seen as if reflected in this place, its resemblance to a distant water sheet is greatly increased.

Very frequently in case of a looming at sea, where the phenomenon occurs across extended water areas during the absence of winds, objects are seen inverted over their real position. Generally, two images are seen; an erect image in what seems to be the true position, and an inverted image above it.

The following story is vouched for by good authorities. On a certain day, in the year 1822, a captain, while at sea, saw the inverted image of a ship in the air. This he immediately recognized as his father's ship, which was at this time so far below the horizon as to be ordinarily invisible. He afterwards found that at this particular time the ship was seventeen miles beyond the horizon.

CHAPTER XXV

THE IGNIS FATUUS, OR THE WILL-OF-THE-WISP

If, by chance, you have ever been misled by an ignis fatuus, you will probably never forget the experience. We will suppose that you have been visiting somewhere in a section of the country where your way home leads across marshy ground, or perhaps near a graveyard, at a time of the year when the vegetable matters in the marshy ground are rotting, and when the bodies of the dead are putrefying more rapidly than usual. It is late at night; there is no moon, and the way is lonely. You are, perhaps, beginning to doubt whether you are on the right road. Suddenly, however, in front of you, you see an unsteady light, moving to-and-fro looking exactly like a lantern carried by some person walking.

"Now I'm in luck," you say. "There is some one with a lantern. Very likely I know him. I'll go faster and catch up; for company just now will be very pleasant."

As you hurry on the light dances fitfully. But it is extremely difficult to catch up with it; for it does not shine continuously, and it takes a very irregular path. At last, when you have come almost up to the light it suddenly disappears. Thinking that the person carrying it has gone ahead in the gloom, you again push forward in an effort to greet the other lonely traveller, and at last succeed in getting near enough the light to see it distinctly. But it is not the friendly light of a lantern. It is merely a pale, ghostly flame that burns for a few moments near the surface of the ground. Sometimes it bursts out in a flare, and then almost dies out. There is something so uncanny about it all that you begin to shiver with fear, and wonder whether the light is not carried by some malign power who is thus endeavoring to lead the way to your death in the lonely morass.

The resemblance of the ignis fatuus to the light of a lantern, carried by some one who is walking, has given to it the name of *Jack-of-the-Lantern*, or *Will-of-the-Wisp*.

The following description of the ignis fatuus will, I am sure, prove interesting.

A young man was walking home one night with a young lady. They had been visiting at a house in the neighborhood of a swamp, and had not left until a late hour. The night was dark; and while crossing a bit of swampy ground they saw a light approach that they believed to be a lantern carried by one of the neighbors. They walked rapidly towards the light and were horrified to see, not a welcome lantern, but a blue flame that burned fitfully but a few feet above the surface of the ground, dancing to-and-fro. Horrified at the ghostly sight they turned around, rushed madly to the house they had left, told their story and spread the terror of the ghostly visitor.

There are cases on record where the flames of the ignis fatuus have not only been approached by an observer, but have remained in one place for a sufficient length of time to permit not only a close examination, but even some experimentation. Professor Knorr, of Kiew, while a student in Germany, had the good fortune while wandering at night in a piece of marshy ground, to see an ignis fatuus that remained steadily in the same place. The light was burning in a portion of the swamp where high reeds were growing among a clump of alders. It burned steadily enough, and with sufficient brilliancy to illumine the surrounding objects distinctly. The ground was too marshy to permit him to reach the flame; but by means of a wooden stick he was able to beat down the rushes sufficiently to permit a closer examination of the light. It was seen to consist of a flame about five inches in height and about an inch and a half in breadth. It was of a pale yellow color at the centre, but was tinted with violet at the edges, and continued to burn quite steadily. It did not seem, however, that the flame possessed any heat, for he could not detect the slightest charring of the wood. As we shall afterwards see, it would not be safe to conclude from this observation that the ignis fatuus possesses no heat.

The ignis fatuus is sometimes seen in graveyards. This has given rise to the belief that these wandering lights are the ghosts of the dead, who come again to earth for the purpose of warning people that their time to die has come. In Scotland the lights of the ignes fatui are known as *elf candles*. Their appearance near a house is believed to be a sign that some one in the house will shortly die.

An ignis fatuus was observed by the astronomer, Bessel, on a winter night during 1807, on a piece of moorland in Hanover. The night was very calm. A great number of fitful, bluish flames were seen that closely resembled the flames produced by impure hydrogen gas. In some cases these flames were apparently stationary, but at times they moved unsteadily from place to place. Bessel noticed that the lights were seen only in places where the ground had been rendered uneven by the digging of turf, thus permitting the water to collect in small puddles.

I imagine that by this time you are becoming impatient for me to explain, if possible, the causes of this mysterious but wonderful light. I am glad to say that there will be no difficulty in making clear to you how this light is produced. Before attempting to do this, however, I wish to say that you will understand, of course, that some of the conclusions drawn are not to be relied on. For example: the statement that there is no heat in the flame of the ignis fatuus. It is possible, however, that in some cases different kinds of phenomena have been included under the name of ignis fatuus. But, in order to explain what is generally known as the causes of the ignis fatuus I must give you a description of observations made by a Major Blesson, of Berlin, of a number of ignes fatui he observed in a piece of low, marshy ground in Germany. This observer noticed that during daylight there were several places in this ground where bubbles of escaping gas could be distinctly seen; and that, in the same places, during the night, pale blue flames might be seen to rise from the swamp, playing fitfully over its surface. Suspecting that the two phenomena were connected, he visited the place at night and saw, in the places where he had carefully noted the bubbles of gas escaping, the pale bluish flame burning on the surface. On endeavoring to approach these places, the flames apparently receded; and after several unsuccessful attempts to reach them he gave up the attempt.

Now, I wish you to note that Major Blesson, although he ceased to chase the flames with his body, continued, so to speak, chasing them with his mind; for, on thinking the matter over, he came to the conclusion that what made the flames disappear was the motion of the air due to his approach.

He therefore again visited the marsh. As before, on his attempting to approach the light, it disappeared, but going quietly up to the spot where he had seen it he remained still, and, to his great delight, the light appeared directly at his feet; so that he had ample opportunity for observing and experimenting with it. Holding a small slip of paper in the flame, he tried, but unsuccessfully, to light the paper; for the flame every now and then disappeared. Convinced that its extinguishment was due to his breath, he held his mouth away from the piece of paper and even shielded it by holding his coat between the flame and his mouth. At last, under these circumstances, he succeeded in firing the paper. Evidently, therefore, the light of the ignis fatuus is only the flame of a gas liberated by the decomposing matter in the marsh.

There are a number of chemical substances that possess the curious property of spontaneously igniting, that is, igniting without any contact with flame or sparks, as soon as they come in contact with the air. One of these gaseous substances is known as *phosphoretted hydrogen.*

As you know, phosphorus is a very combustible substance. A piece of phosphorus when exposed to the air possesses the power of shining in the dark, and may, under certain circumstances, ignite spontaneously. This is especially the case when the phosphorus is in a very finely divided condition.

There are certain compounds of phosphorus, notably a compound with hydrogen, that exists in the form of a gaseous substance. When this gas is permitted to escape from water into the air, it instantly takes fire with a small explosion. This compound, known as *phosphoretted hydrogen,* can be readily produced by throwing a small piece of a solid compound of phosphorus and hydrogen into water, as represented in Fig. 51. As the solid falls to the bottom of the wineglass, bubbles of gas are given off which rapidly rise through the water, and escape into the air at its surface. As soon as they pass into the air, they instantly burn with a luminous flame. At the same time a wreath of white smoke is produced, like the smoke rings you may often have seen blown from the mouth of the smoker. These rings rapidly increase in diameter as they rise above the water surface.

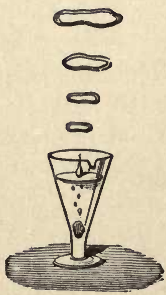


Fig. 51. The Production of Phosphoretted Hydrogen

Phosphoretted hydrogen appears to owe its ability to ignite as soon as it comes in contact with the air, to the presence of an exceedingly inflammable liquid compound of hydrogen and phosphorus, that possesses the power of igniting any inflammable gas when present in exceedingly small quantities.

That the ignis fatuus cannot be due to the presence of pure phosphoretted hydrogen, is evident from the fact that the color of the flame differs from the bright white light produced when pure phosphoretted hydrogen is burned in the air; and, moreover, there is an absence of the white rings that are always produced by the burning of this gas.

There is, however, a gas known as *marsh gas,* a compound of carbon and hydrogen, that is very commonly given off from the marshes, and that burns in the air with a bluish or yellowish flame. Besides marsh gas, there are also a number of other gases that are given off by the decomposition of vegetable and animal matter in the presence of water. As we have already seen, the phenomena of the ignis fatuus is comparatively rare. It would probably be much commoner if the conditions more frequently existed for its ready ignition. These evidently exist only occasionally. It is generally believed that the cause of this ignition is the liberation of small quantities of this highly inflammable compound of hydrogen and phosphorus, that gives to phosphoretted hydrogen its ability to explode spontaneously on contact with air.

Other explanations have been given as to the manner in which the inflammable gas given off by a marsh is ignited. Volta, the inventor of the voltaic pile or battery, in a letter to Dr. Joseph Priestly, in 1776, suggests that the ignition is produced by tiny electric sparks frequently present in the air, especially when foggy. He informs Mr. Priestly that he had frequently caused inflammable air to ignite by passing very small electric sparks through it. It is the general belief, however, that the ignition of the inflammable gas is due, not to the presence of electric sparks, but to some spontaneously inflammable gas like phosphoretted hydrogen.

I think there can be no doubt that the phenomena of the ignis fatuus are due to the ignition of various inflammable gases that are given off by the gradual decomposition of vegetable and animal matter. The gases are ignited by some spontaneously inflammable gas most probably by some of the compounds of phosphorus and hydrogen. That such gases are not always ignited as they escape into the air, is probably due to the different quantities of air with which they are mixed, or to the absence of the phosphoretted hydrogen. It has been suggested, and apparently with good reason, that, possibly, the cause of the sudden change in the position of the light is due to the collection of a large quantity of this gas near the surface, that is gradually ignited in spots, either by the presence of a neighboring flame or by the sudden liberation at that place of the necessary phosphoretted hydrogen.

It has also been believed that there may be another cause for the light of the ignis fatuus. Sir Isaac Newton suggests that this light is due to the presence of a species of phosphorescent light, like that of the firefly or the glowworm.

It is possible that some varieties of the ignis fatuus are of this general character. It is improbable, however, that this is frequently the case; since most of the ignes fatui are caused by the burning of an inflammable gas liberated from the marshy land, and produced by the decomposition of vegetable matter.

CHAPTER XXVI

SO-CALLED PERPETUAL LAMPS OF THE ANCIENTS

Since in ordinary lamps the light is as much due to the oxygen of the air as to the oil or other combustible, lamps will properly come under the subject of atmosphere.

It is an unquestioned fact that many of the sepulchres of the ancients, when opened, were found to contain air-tight vessels, bearing inscriptions to the effect that lighted lamps were shut up in them, that would continue to burn and give off light forever. Moreover, when such vessels were opened, flames actually issued from the lamps within. It seemed, therefore, that the lamps had been burning ever since the sepulchres were sealed up.

Such lamps are so wonderful that we should try to find out what is known concerning them. In one of the chapters of a very curious book, published in London in the year 1708 by John Wilkins, Bishop of Chester, considerable attention is given to the question of what was known to the ancients as *subterranean lamps.*

Among other stories told by Bishop Wilkins is that concerning the lamp of a man known as Olibius. This lamp, it is claimed, continued burning for 1,500 years. A countryman, while digging in the neighborhood of Padua, Italy, came across an urn or earthen pot, inside of which was found another urn, and in this second urn a burning lamp. On each side of this there were two other vessels, each of them filled with a pure liquor, one of gold and the other of silver. It is uncertain, however, what relation, if any, these other vessels had to the burning lamp.

Another story is told of a lamp that was found in the tomb of Pallas, the Arcadian, who was slain by Turmus in the Trojan War (which occurred possibly about 1104 B. C.). This lamp was burning when opened in the year 1401, from which it might seem that it had been burning for over 2,500 years. Wilkins says concerning this lamp that "being taken out, it did remain burning, notwithstanding either wind or water with which some did strive to quench it; nor could it be extinguished till they had spilt the liquor that was in it."

It may have seemed to you while reading these accounts that it would be impossible for a lamp actually to continue burning for so long a time. Such a conclusion would, indeed, be quite correct; for light, like heat, is only a form of energy, and cannot be produced without the expenditure of energy. So that supposing a lamp could be constructed that would require the consumption of an exceedingly small quantity of energy, yet, after a while, such a store would at last be exhausted, and the lamp would necessarily cease burning—not in a hundred years, nor, indeed, in a single year, but most likely in a few days at the most. Moreover, all cases of combustion with which we are acquainted requires not only the presence of a combustible body, that is, a body capable of burning, but also the presence of another body capable of entering into combination with it, and thus causing the burning; and this is generally the oxygen of the air.

We can safely conclude that such lamps were not burning during the time claimed. It is possible, however, to explain readily and simply how lamps might have been constructed that if buried over 2,500 years ago, or for the matter of that 5,000, or 10,000 years ago, would be found burning when opened and thus exposed to the air.

I will endeavor to explain how very simple this apparently wonderful thing is. In the first place the people who sealed the lamps in the air-tight vessels knew that they would be spontaneously lighted as soon as the materials with which they were filled came in contact with the air. The people who opened them, expecting to find them burning, and on seeing the flame, believed that they had been burning from the time they were sealed up in the vessels.

As you can see, this explanation is not unlike the explanation of the light of the ignis fatuus. Only in the case of the ignis fatuus, the inflammable gas, produced by the gradual rotting or decomposition of vegetable or animal matter, is ignited immediately after it is formed, or as soon as it escapes through the water of the marsh and comes in contact with the oxygen of the air. But in the case of the so-called perpetual lamp, instead of the ordinary oils and wicks found in common lamps, they probably consisted of chemical substances of such a nature as to instantly ignite when the vessel containing the lamp was opened, and the oxygen of the air was thereby permitted to come in contact with them. This ignition occurring almost instantaneously, it appeared to those opening the lamp that it had been actually burning from the day it was sealed up.

I will not pretend to say that I know just how such lamps were made. Assuming the above explanation to be true, which by the way is one of the explanations that Bishop Wilkins mentions, but does not seem disposed to believe, I will say that I feel sure that I could devise a lamp of this character.

During the times when such lamps were buried in sepulchres, little or nothing was known of chemistry. There was, however, a study known as *alchemy*, which may be regarded as the beginning of the science of chemistry. A belief existed that it was possible, by subjecting the commoner metals, such as lead, iron, tin, etc., to certain operations, to convert them into gold. In order to bring about such changes, the alchemists tried many curious experiments, during which they subjected all kinds of substances to various processes somewhat resembling baking, boiling, frying, or roasting by fire; or they endeavored in various ways to change solid substances into liquids by subjecting them to the action of various solvent liquids. Now, the processes to which the materials were subjected were not unlike the processes employed to-day by chemists. So it came to pass that some very curious facts in chemistry were discovered.

Of course, the alchemists were unsuccessful in discovering what they called the *Philosopher's Stone*, or a substance by which the baser metals could be transformed into gold. They did, however, obtain curious bits of information which they were able to sell; so that when the custom arose among the very wealthy people of burying, with the bodies of their loved ones, lamps that it was claimed would continue burning forever, an opportunity was afforded the alchemists to make gold or money in another way. I do not doubt that much money was thus made, and a rivalry existed between different alchemists in the preparation and sale of their so-called perpetual lamps.

Let us suppose, for example, that some of these alchemists in their experiments had discovered two very common chemicals, namely, *phosphorus* and a liquid known as *carbon bisulphide*, a combination of carbon and sulphur. Now, this liquid possesses the power of completely dissolving phosphorus, producing a golden colored liquid, possibly the golden colored liquid referred to in one of the stories I have quoted from Wilkins of the perpetual lamps.

Suppose a lamp containing an ordinary wick were filled with carbon bisulphide in which a lot of phosphorus had been dissolved, and quickly shut up in an air-tight vessel; I have no doubt such a lamp would spontaneously ignite when the vessel was opened. If you doubt this, let me tell you of a simple experiment that can be tried, although I must caution you if you think of repeating this experiment, to be very careful, as you might otherwise set either yourself or your house on fire.

Having dissolved a small piece of phosphorus, say as large as a grain of rice, in about half a teaspoonful of carbon bisulphide, pour the liquid on a piece of newspaper, crumpled up so as to occupy a comparatively small space, but at the same time not crumpled so closely as to prevent the entrance of air. Having done this, stand off a little distance and watch the paper. As the carbon bisulphide evaporates the phosphorus is left in a finely divided condition on the surface of the paper. It begins at once to enter into combination with the oxygen of the air and in a few moments will burst into flame, igniting spontaneously.

CHAPTER XXVII

THE ELECTRICITY OF THE ATMOSPHERE

Of all the wonders of the atmosphere there is probably none that produces a deeper impression on the human mind than powerful lightning flashes. When lightning strikes across the dark, angry clouds that cover the sky, the accompanying peals of thunder together with the furious winds and torrents of rain that generally attend a thunder-storm, deeply impress us.

The ancient Greeks believed they saw in the thunderbolt, with its accompanying angry mutterings, the great Jupiter hurling fiery bolts at his enemies. The ancient Scandinavians believed the flash and the roar of the thunder-storm were caused by their deity, Thor, moving against his enemies in his war chariot. The lightning flashes were the angry gleams from his eyes, and the peals of thunder the rumbling of the wheels of his chariot as it dashed though the heavens. Somewhat similar ideas existed in practically all parts of the ancient world.

From the earliest times the lightning flash was believed to predict the future. Indeed, so highly esteemed were its powers in this direction that its indications were believed to set aside all other auguries.

The Etruscans were generally believed to be more deeply skilled in interpreting the future by the appearances of the lightning flash than any other ancient people. Etruria, the home of the Etruscans, was the name given to that part of Italy which lies between the Mediterranean Sea and the Apennine Mountains on the one side, and the Tiber and the Magra Rivers on the other side. This country was well settled long before the foundation of Rome, 653 B. C. It was a federation of twelve large cities, each of which formed an independent republic.

The Etruscans divided lightning flashes into different classes, according to the character of the omens. They asserted that each kind of flash bore with it a certain message from the heavens. Some flashes meant that one of the many religious sacrifices had either been entirely neglected, or improperly performed. Others indicated that a certain place, or a certain course of action, was to be carefully avoided. Some indicated that an evil which appeared to threaten the country was not to be dreaded; and that other things were to be greatly dreaded because, although they appeared to bring good fortune, they would in the end prove calamitous. Still other flashes were regarded as of great public import.

The Romans divided lightning into flashes that occurred during the day which were believed to be produced by Jupiter, and flashes occurring during the night which were believed to be due to Symmanus. At the time Italy was peopled by the Etruscans it was subject to the same severe thunderstorms as it is to-day. When a person was killed by a lightning flash the anger of the gods was indicated. But, if they were merely slightly injured, the sparing of their lives was regarded as a special favor. In a similar way any building, or part of the earth that has been struck by a lightning flash, was ever afterwards consecrated to the gods and protected by the erection of a fence around it. This was especially the case where bolts made small openings in the ground.

There is always a certain quantity of free electricity in the atmosphere. It is not certain just how this electricity is produced, its presence being ascribed to a variety of causes. In the opinion of some it is due to the friction of air against the earth, or of the particles of air against one another. Others think it is due to a similar friction of water particles against one another, against the air particles, or against the surface of the earth. Still others ascribe it to the evaporation of water, or to differences in temperature.

When water containing dissolved salty matters, such as the water of the ocean, evaporates, the vapor rising from it is always charged with free electricity. As you probably know, there are two kinds of electricity, *positive electricity*, like that produced on a glass rod that is briskly rubbed with a dry silk handkerchief, and *negative electricity*, such as is produced on a cake of resin when rubbed by fur. Since on the evaporation of ocean water, the vapor which rises into the air always contains a charge of positive electricity, while the ocean is left with a negative charge, Pouillet, one of the early French electricians, suggested that the free electricity of the air is due to the evaporation of the water of the ocean by the heat of the sun; and many well-known electricians of the present day are of the opinion that, at least, some of the free electricity of the atmosphere is due to this cause.

There are also, besides the above, other causes to which the free electricity of the air may be due. It cannot be said which of them is the real cause. Indeed, it seems probable that all of them are, to some extent, active.

Long before the true cause of electricity was discovered, it was suspected by scientific men that the lightning flash and the electric spark, or discharge, might be due to the same force. The glory of the discovery, however, of the identity between the lightning flash and electric discharge, is to be given to that remarkable, many-sided man, Benjamin Franklin, the great physicist, poet, plenipotentiary, printer, and philosopher.

Franklin passed much of his life in Philadelphia. It was in this city that he first succeeded in drawing the electricity from the clouds, thus immortalizing himself. This great experiment was made some time during the month of July, 1752.

It appears that, several years before this time, Franklin had reached the conclusion that the lightning flash and the electric spark were identical. In answer to an inquiry made by a friend in a letter dated March 18th, 1755, asking him how he came to think of making this experiment, Franklin wrote as follows:

"Your question, how I came first to think of proposing the experiment of drawing down the lightning, in order to ascertain its sameness with the electric fluid, I can not answer better than by giving you an extract from the minutes I used to keep of the experiments I made, with memorandums of such as I purposed to make, the reasons for making them, and the observations that arose upon them, from which minutes my letters were afterwards drawn. By this extract you will see that it might have occurred to any electrician.

"'November 7th, 1749. Electrical fluid agrees with lightning in these particulars: 1. Giving light. 2. Color of the light. 3. Crooked direction. 4. Swift motion. 5. Being conducted by metals. 6. Crack or Noise in exploding. 7. Subsisting in water or ice. 8. Rending bodies it passes through. 9. Destroying animals. 10. Melting metals. 11. Firing inflammable substances. 12. Sulphurous smell. The electric fluid is attracted by points. We do not know whether this property is in lightning. But since they agree in all the particulars wherein we can already compare them, is it not probable they agree likewise in this? Let the experiment be made.'"

As you see, the date of these notes was 1749, while the date of the experiment was 1752. You may, therefore, be surprised that Franklin let so long a time elapse before actually flying the kite in Philadelphia. It appears, however, that Franklin's original idea was to erect a species of sentry box on the top of a high tower. Through the top of this box a wire was to have been extended upwards into the air, its lower end reaching to the bottom of the box, from which it was insulated by a large cake of resin. This box was to be large enough to hold a man standing on the cake of resin. Franklin argued that, if an electrified cloud passed over the rod, sparks could be drawn from its lower end by the man approaching his knuckle to any part of the iron rod. But Franklin was not idle during the time between 1749 and 1752. He was so convinced that lightning and electricity are identical that, employing charged conductors to represent clouds, he began a series of experiments for the purpose of devising means for protecting buildings against the disastrous effects of lightning flashes. These means consisted of insulated rods attached to the sides of buildings, the upper ends of the rods terminating in points, and the lower ends being in good electrical connection with the ground. It was in this way that his great invention of the *lightning rod* was made, some years before lightning was actually drawn down from the sky.

There was no church steeple or high building in Philadelphia at the time referred to by means of which Franklin could make his experiment with the sentry box. At last, getting tired of waiting for the erection of such a building, Franklin conceived the idea of reaching the clouds by means of a kite. He therefore made the Philadelphia kite, the fame of which has gone out all over the world.

Franklin's kite did not differ from the kite that is used by boys to-day; doubtless some of you have made and raised one like it many a time. Instead, however, of pasting paper over the frame, he used silk in its place; for he knew that when the kite was raised during an approaching thunderstorm, the rain would wet the paper and ruin the kite. In other respects, however, the kite was like the ordinary kite, except a metallic wire reached above the top, and was connected at its lower end with the string by which the kite was raised. It was a bold idea. The experiment was attended by far greater dangers than Franklin apparently appreciated; for he does not seem to have taken any of the precautions which subsequent experiments with electric kites have demonstrated to be necessary for the safety of the experimenter.

Armed with this kite on a day in July, 1752, when the weather conditions seemed to promise a heavy thunderstorm, Franklin proceeded to some vacant lots in Philadelphia. According to the best information I have been able to obtain, these lots were probably situated at the top of a hill somewhere in the neighborhood of Eighteenth and Spring Garden streets. Franklin took with him his son, not, I believe, because he feared his townsfellows would laugh at seeing a grave philosopher flying a kite, as has been suggested, but rather, because he felt sure that, so many years having passed since the time he raised kites as a boy, his son would be able to give him valuable pointers in this great art.

Franklin and his son at last reached the top of the hills, and raised the kite. He had connected a silk ribbon, silk being a non-conductor, to the end of the string with which the kite was raised. He then placed himself under a shed, holding the ribbon so as to keep it under cover, and so prevent the rain from wetting it, and thus destroying its insulating powers.

The kite was raised by means of a hempen cord, a partial conductor. A heavy cloud, apparently charged with lightning, was seen to pass directly over the kite, but Franklin missed the bristlings of the fibres that he knew from experience would have taken place had the kite and string been electrified. He had tied a key to the end of the kite string where it was attached to the silk ribbon. His idea was that if some of the electricity of the clouds was communicated to the kite, it would flow down the hempen cord and charge the key, so if it were true, as he believed, that lightning and electricity were the same, he ought to be able to obtain electric sparks from the key. There were no signs of electricity in the string, but still he would try. He therefore presented his knuckles to the key but was unable to obtain the smallest spark. It was, indeed, a great disappointment. It seemed that his reasonings were incorrect and that lightning and electricity were not the same thing.

Fortunately, however, the rain soon began to fall, and wetting the kite string, made it a better conductor. The fibres of the cord now stood out in a bristling manner; the kite was evidently charged with electricity; so, again holding his knuckles to the key, he obtained a bright spark which he recognized as an electric spark. It was lightning. Franklin had made the discovery that he had expected to make, and felt that he was immortal.

It is needless for me to tell you that, in order to test the identity between lightning and electricity, Franklin took samples of the fire he had thus drawn down from the sky, and tried numerous experiments, proving that they possessed the same power as the sparks from his electric machine. With them he charged Leyden jars, rang his chime of electric bells, attracted and repelled pith balls, and performed the various other experiments he was accustomed to try with ordinary electricity. He had, therefore, proved lightning and ordinary electricity to be identical.

While Franklin was waiting for the erection of a tall building on which he could place his sentry box, it appears that one of his papers had been published in France, describing the experiments he had made in Philadelphia, to show the possibility of protecting buildings from lightning by means of pointed conductors. This paper had been brought to the attention of the Royal Society of London by whom it was very unfavorably received. It appeared that the Society could not understand how Franklin could have formed so clear a conception of the cause of lightning, as to actually plan the invention of the means for protecting buildings against lightning flashes.

I suppose that, to some extent, the Royal Society may be pardoned for their lack of faith; for Franklin was practically describing to them the construction of a device intended to protect buildings against the destructive effects of electric discharges, before he had proved that lightning and electricity were identical. It seems, however, that what the Royal Society refused to publish, was published elsewhere; and a copy of this publication being reprinted in Paris, came under the notice of the King of France. The King was so deeply interested in this paper that three Frenchmen, D'Alibard, De Lor, and De Buffon, determined to make the experiment Franklin suggested, by drawing down lightning from the clouds by means of a pointed rod, and to show the same to the king. The three men agreed to make their experiments independently of one another. They did this *and were all successful in drawing electricity from the skies*, before Franklin did so. The first of these was D'Alibard, who made his experiment on the 10th of May, the second De Lor, on the 18th of May, and the third De Buffon, on the 19th of May, 1752.

D'Alibard's experiment was made by erecting an iron rod forty feet high in a garden in a little village eighteen miles distant from Paris. This rod was erected according to Franklin's directions, and was insulated at its base which rested on a table placed inside a small cabin.

Franklin's kite experiment created great excitement throughout the scientific world, and was repeated by quite a number of other experimenters. It will be impracticable to refer to any of these later experiments. I may, however, briefly refer to one other case, in which considerable discharges of electricity were drawn from the skies by means of a kite. This was the experiment tried on the 7th of June, 1753, by a Frenchman, De Romas, who had built a kite seven and a half feet high, and three feet wide, with eighteen square feet of wind surface. In order to render the hempen cord employed for raising this huge kite a better electrical conductor, De Romas had a wire interwoven between the strands. In place of the key that Franklin attached to the end of the cord, De Romas employed a tin tube insulated from the ground, but connected with the lower end of the kite. During one of his experiments, after the kite had been raised to a height of 550 feet above the ground, De Romas drew sparks from the tin tube that resembled miniature lightning flashes; for they were three inches long, a quarter of an inch thick, and produced, while passing through the air, a snapping report loud enough to be heard at a distance of about 200 paces.

Another experiment of drawing electricity from the clouds was made on the 6th of August, 1753, by Professor Richmann, of St. Petersburg. This experiment resulted in the death of Richmann.

Richmann had erected on the roof of his laboratory an insulated vertical iron rod that communicated by means of a metallic chain, also insulated, with a metallic rod attached to the ceiling of the laboratory. This rod projected downwards a short distance from the ceiling, where it ended in a metallic ball. In order to be able to see whether this apparatus had been electrified by the air, Richmann had attached a thread to the side of the rod. When the rod contained no electric charge, the thread hung vertically downwards, resting against the metallic rod, but when the rod was charged, it electrified the thread, and caused it to stand out at an angle depending on the amount of the charge.

One day, while Richmann was observing the movements of the thread, he unfortunately brought his head too near the rod. Instantly a globe of blue fire, as large as a man's fist, darted from the rod to his head through a foot of air that separated the two. Richmann was instantly killed, while a gentleman who was with him was so stunned as to be unable to give any account of what had happened after the bolt struck Richmann.

It will interest you to know that some have asserted that the electric fire had been drawn down from the sky long before the time of Franklin; and that, in point of fact, the story about Prometheus stealing the sacred fire from heaven only describes the fact that Prometheus had succeeded in kindling a fire by means of an electric discharge drawn from the clouds.

According to ancient mythology, Prometheus, the brother of Atlas, was especially distinguished from other men by reason of his cunning. It seems, however, that he had provoked the anger of Jupiter by ridiculing the gods. To punish both him and the people on the earth, Jupiter took away the sacred fire from the earth; but Prometheus, aided by Minerva, climbed to the heavens and stole the fire from the chariot of the sun. Jupiter punished Prometheus for this impious act by chaining him to a rock on Mt. Caucausus, where he was condemned for 30,000 years to have a vulture feed on his liver, which, although constantly devoured, was continually miraculously renewed, thus per mitting the pain to continue for this great length of time.

Whether or not Prometheus actually did so draw down the lightning from the sky, we cannot of course say. He was a bright man, however, and may have got so far ahead of the rest of the world as to have actually made this discovery.

But Prometheus is not the only one who is thus credited with an early electrical knowledge. It is said that the Roman, Numa Pompilius, succeeded on several occasions in safely drawing down the sacred fire from the sky, but that another Roman who came after Pompilius, Tullus Hostilius, having found some notes that had been left by Numa on the sacred art of worshipping Jupiter, had been struck dead by a lightning flash.

That there frequently exists large quantities of free electricity in clouds and fogs, can be shown in a variety of ways. Probably one of the best of these is by means of some experiments made in England by a gentleman named Crosse. Crosse had been repeating Franklin's experiments of drawing electricity from the air. For this purpose he had erected a long insulating wire, suspended by means of poles that projected above the tops of the tallest trees in his park. The wire so strung over the tree-tops was more than a mile in length. It was carefully insulated from the trees and the poles on which it was placed by means of non-conductors, and connected with his laboratory, where it was so arranged that the electricity it collected charged and discharged a Leyden jar battery containing fifty large jars.

CHAPTER XXVIII

LIGHTNING AND THUNDER

Thunderstorms occur in nearly all parts of the world, except in the higher latitudes of the Arctic and the Antarctic zones.

The thunderstorms so common in the temperate zones, occurring either late in the afternoon, or early in the evening of a hot, sultry day, are called *heat thunderstorms*, or *thun-*

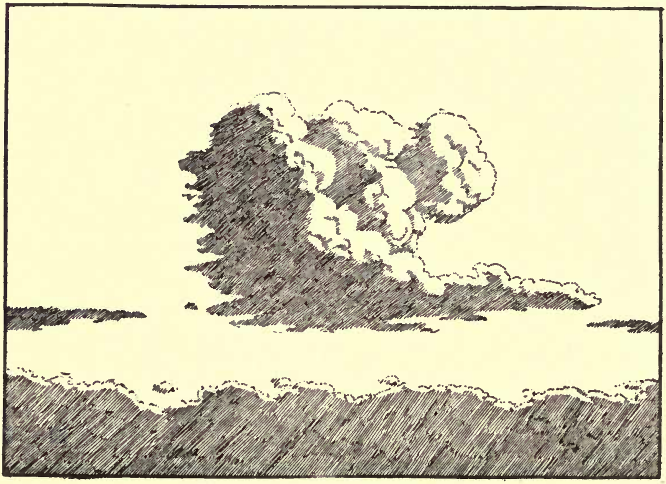


Fig. 52. Thunder Head.

der gusts. They belong, like *cyclones*, to the class of *travelling storms*.

Several hours before a thunderstorm bursts, peculiar rounded masses of lurid looking clouds known as *thunderheads*, such as are represented in Fig. 52, can be seen slowly rising in the west. They generally collect in a mass near the western horizon. From near the top of the bank of clouds, a forerunning layer of fleecy, feathery cirro-stratus clouds may be seen extending rapidly towards the east and collecting in horizontal bands in the higher regions of the atmosphere. As these clouds advance rapidly, they grow thicker on the eastern side; and a festoon of clouds begins to slowly descend and dissolve from the lower surface. In the meantime, the rain-bearing bank moves rapidly to the east. The air, which has been oppressively warm, now grows slightly cooler as the fore-running bank of clouds hides the sun. As the clouds approach, distant thunder is heard; when below the level base a *gray rain curtain* appears which

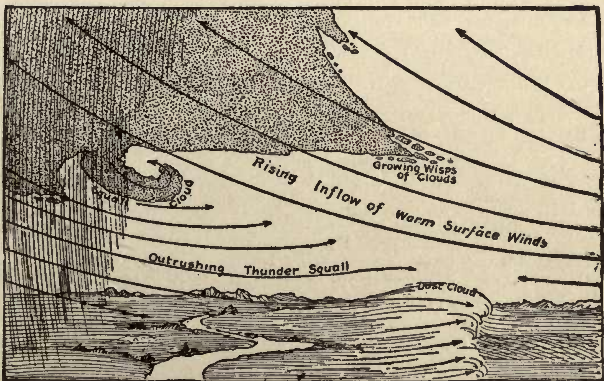


FIG. 53. APPROACH OF THUNDER STORM

trails on the ground, hiding objects behind it. Small detached clouds form in front, and, rapidly increasing in size, are merged with the advancing storm-cloud which overtakes them. At the same time a *ragged squall cloud,* better shown in Fig. 53, of a light gray color, rolls beneath the dark cloud mass.

The storm advances broadside over the country with a velocity of twenty to fifty miles an hour. A short-lived squall cloud, Fig. 53, brings with it clouds of dust, and advances rapidly below the rain-cloud. The temperature falls quickly, frequently from ten to twenty degrees in less than half an hour. The rain falls at first in large pelting drops; but these soon decrease in size, but increase in quantity, until there is a heavy downpour. Hail frequently attends thunderstorms. The vivid flashes of lightning, followed by thunderclaps, become more and more frequent as the centre of the storm comes more nearly overhead. The storm passes rapidly; the thunder and lightning become less frequent; the dark shadow in front of the storm becomes less marked; the lightning flashes finally cease entirely; the rain stops, clouds break in the west, a clear sky appears, the air becomes cooler and the storm is over.

I have often sat watching a passing thunderstorm in the city of Philadelphia, noting the changes above referred to. One can readily tell when the storm is approaching; when it is nearly overhead; and when it is passing further and further away, by the intervals that exist between the lightning flashes and their accompanying thunder. When the storm begins, quite a considerable time elapses before the thunder is heard after the lightning flash so that one knows it has struck at a distance. As it comes more nearly overhead, the intervals between the lightning and the thunder become shorter and shorter, until, when almost immediately overhead, the thunder peal follows the lightning flash almost instantanously.

It may be a matter of no little comfort to those who are sensitive to lightning flashes to know that, as long as a fairly long time elapses between the lightning flash and the thunder peal, the discharge has struck the earth at a considerable distance from where they are. Of course, you understand that the peal of thunder always follows the lightning flash instantaneously. The reason you can see the flash long before you can hear the thunder is because light travels so much more rapidly than sound. The light waves from the flash and the sound waves from the thunder begin to move towards you at practically the same time, but the lightning flash is visible long before the thunder crash is heard. It is only when the flash and the thunder peal are very near together that there is any danger of a bolt striking near where you may be. Remember this when in a thunderstorm and you may not only be able to comfort yourself, if such comfort is necessary, but also any who may be with you.

People are more apt to be frightened by the thunder than by the lightning flash. If you ever meet such people, assure them that the thunder is harmless. It is lightning that kills, and death by lightning stroke is so nearly instantaneous that, if one lives to hear the thunder, there is no occasion for worry, since the danger is over, at least so far as that particular bolt is concerned.

People generally give themselves unnecessary worry about the danger attending thunderstorms. Many deaths are caused by this mighty force; but the number of people so killed is exceedingly small when compared with those killed by other causes. Arago, the French physicist, very sensibly remarks that a loose tile falling from a roof, or a flower pot from the window of a house, are far more dangerous than lightning flashes; for more people are killed in Paris from such causes than by bolts from heaven.

The United States Weather Bureau has made a careful study of the thunderstorms of the United States. It would appear from this study that there are three regions where thunderstorms are especially common. One of these is situated in the southwest with its crest over Florida. One is in the Middle Mississippi Valley, and the other in the Middle Missouri Valley. In the region over Florida there are forty-five days in every year during which thunderstorms occur. In the Middle Mississippi Valley there are thirty-five days of thunderstorms every year, and in the Middle Missouri Valley there are thirty thunderstorm days in each year.

An attempt has been made to determine from the number of people killed in the United States the positions of greatest danger during thunderstorms. During the year 1900, there were 713 people killed by lightning flashes in the United States. Now one might think that by finding where the greatest number of people died, it could be easily determined what places are most dangerous. Let us look into this matter and I think I can prove to you that such is not the case. Of the 713 people who were killed, 291 were killed on the highways, 158 in houses, 57 under trees, and 56 in barns. It might, therefore, seem at first sight that it is far more dangerous to be in a house during a thunderstorm than under a tree. But, in point of fact, the most dangerous place one can be in during a thunderstorm is under a tree, and the safest place, in a house. More people were killed in houses than under trees, not because the houses are more dangerous, but because the great majority of people are sensible enough to remain in doors.

It is not my intention in this volume to discuss the manner in which a lightning rod acts, or to tell you how it was that Franklin came to invent it. This is a subject that will be more properly discussed in the "Wonder Book on Electricity." For the same reason, I do not think it necessary to do more than state the fact that tall objects are more apt to be struck by lightning flashes than low objects; and that it is for this reason that ships at sea are so frequently struck during thunderstorms. Nor, will I attempt to explain the difficulty in obtaining a good connection of the lower end of a lightning rod of a ship with the water of the ocean.

The thunder which accompanies the lightning flash is due to the rushing in of the air to fill the vacuum caused by the sudden expansion of the air through which the bolt is passing. This vacuum is greatly increased by the formation of clouds of expanding steam, caused by the evaporation of the raindrops through which the discharge has passed. The sudden formation of masses of vapor to some extent drives the air away; and the vapor afterwards being rapidly condensed leaves a more or less complete vacuum.

The rolling or rumbling of thunder is due to the sound reaching the observer at different times. Lightning flashes being sometimes many miles in length, the sound will reach the observer's ears from the nearest portions of the flash before it does from the more distant portions. Reflection of the sound waves from the clouds, as well as from masses of air at different elevations, also tends to increase the rumbling or rattling sound.

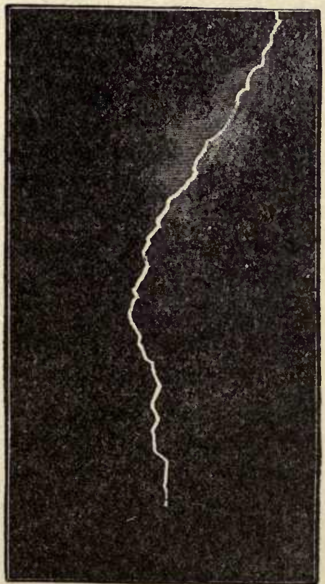


Fig. 54. Forked Lightning

The so-called *zigzag*, or *forked lightning* takes its name from the belief that the path of the discharge is zigzag or angular, that is, that the discharge suddenly changes its path. In point of fact, photographs of a lightning flash when carefully examined show that the path of the discharge, so far from being characterized by sharp angular bends, follows a winding course not unlike the channel of a river in its lower course. This can be seen from an examination of Fig. 54.

When an insulated conductor, placed near an earth-connected conductor, but separated from it by a non-conducting material, such as air, is being charged, and the charge gradually increased, a point is at last reached when it is discharged by means of a flash, or spark, that passes through the air to the earth-connected conductor, and so to the earth. This kind of discharge is called a *disruptive discharge.* When the distance between the two conductors is considerable, this discharge assumes an irregular form, somewhat zigzag in shape, but in reality possessing the rounded bends of the zigzag or forked lightning Such a discharge is shown in Fig. 55.

A curious modification of zigzag, or forked lightning is seen in what is known as *multiple*, or *ribbon lightning.*

FIG. 55. DISRUPTIVE DISCHARGE

This is a rare form of lightning in which the discharge consists of a number of separate parallel discharges such as shown in Fig. 56, from a photograph by Mr. John M. Justice, of Philadelphia.

Heat lightning is a form of lightning in which the discharge assumes the form of an expanded flash that lights up the surfaces of surrounding clouds. This form of lightning is not attended by thunder. It is due to the reflection from the clouds of lightning flashes that have occurred at too great a distance to permit the thunder to be heard. Heat lightning is sometimes called *summer lightning.*

Globular lightning is a rare form in which the discharge takes the shape of a globe of light that remains stationary in the air, or moves slowly through it. The exact cause of globular lightning is unknown.

When the globe of lightning reaches the earth it moves in an irregular path, sometimes quietly and sometimes with a hissing noise. Frequently the globe of fire explodes with a tremendous force, causing great damage to things in its neighborhood. A story is told of a globular lightning discharge in which a ball of fire rolled quietly down the chimney of a house into the kitchen, and slowly across the floor, finally leaving the room through a crack in the wall. Although a number of people were in the room, no one was hurt.

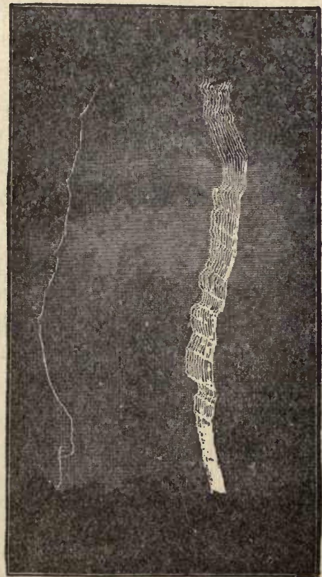


FIG. 56. RIBBON LIGHTNING

Bead lightning is another rare form of lightning in which the discharge assumes an appearance somewhat resembling a number of beads strung on a string.

Volcanic lightning is a name given to electrical discharges that occur in the air near the craters of volcanoes during eruptions. Lightning discharges of this character are sometimes very powerful. The great intensity reached by this form of lightning is to be attributed to the great quantities of electricity that are liberated in the air near the craters. This is due to some extent to the friction caused by the explosive escape of lava, but in much greater degree to the rapid condensation of the immense quantities of water vapor that are set free during an eruption.

In the eruptions of Vesuvius, Etna, and, indeed, all volcanoes in which the lava is thrown to great heights, the appearance of frequent flashes of lightning around the crater is common. During the great eruption of Krakatoa, in the Straits of Sunda, west of the island of Java, an eruption which has, perhaps, never been equalled in severity, the lightning flashes that played around the crater in the neighborhood of the column of ashes that was violently thrown up in the air, were of a peculiarly terrifying character.

Death by lightning appears to be instantaneous. Where people have survived a lightning stroke, they are unable to remember having been struck, or having seen, heard, or felt anything. When struck by lightning the body almost always falls directly to the ground. In some cases, however, death has been so sudden that the bodies retain the attitudes they had when death overtook them. Cardan tells of eight reapers, who, during a thunderstorm, had repaired to the shelter of a tree and were eating their noonday meal, when they were all struck by a flash of lightning. When the storm was over, people passing by believed that the reapers were still eating, for their bodies retained the exact positions in which they had died. One was holding a glass in his hand as if about to drink. Another was carrying food to his mouth, while a third was reaching over to take something from a dish.

A very curious effect sometimes observed in those killed by lightning is that the bodies are completely stripped of their clothing. Somtimes the clothes are entirely consumed, and at other times are torn off the body and found a great distance from it. It is not, however, generally the case that people so stripped are killed by the lightning discharge. On the contrary, many cases are on record where, having been stripped of all their clothes and the clothes having completely disappeared, the people have soon regained consciousness without having been seriously injured. In these cases the removal of the clothes is probably due, not to the lightning flash, but indirectly to the rush of air that causes the thunder. As the air rushes by the person, a vacuum is produced and the air between the body and the clothes suddenly expanding, completely strips the clothes off the body.

Electricity, it is claimed, possesses wonderful curative powers. And, indeed, when intelligently applied, has sometimes produced wonderful cures. Of course, in such cases, it is necessary for the force of the electricity to be intelligently regulated by the doctor. It appears, however, that sick people who have accidentally received powerful lightning strokes have sometimes been wonderfully improved in health thereby. There is no doubt whatever that these unexpected and unusual cases of electrical treatment have resulted in restoring sight to the blind, hearing to the deaf, and speech to the dumb. So, too, people who have suffered for many years from paralysis, have suddenly recovered the ability of moving their limbs after a stroke of lightning. Despite these facts, however, and their authenticity appears to be unquestioned, I very much doubt whether many could be found to take the risk of electrical doses applied with so lavish a hand.

Before closing this chapter reference should be made to the so called *lightning photographs* that are frequently found on the bodies of those killed by lightning flashes. The commonest of these markings are various tree-like forms. Now, since dangerous lightning flashes are most common in summer when the people killed are apt to be under trees, it is natural, perhaps, to believe that these markings are photographs of the trees. It is far more likely, however, that they are only the engorged blood vessels, or capillaries near the surface of the skin, that have been filled with blood by physiological causes connected with the shock.

But there are cases in which markings other than those of trees have been found on the skin. Flammarion tells the story of a monogram consisting of two Roman letters being impressed on the thigh of a man struck by a lightning flash. On being taken to the hospital the resident physician was greatly surprised on recognizing this monogram as the same as one marked on a steel plate of a tortoise shell purse he had recently lost. Inferring from the position of the mark on the man's thigh that it was the photograph of a purse, probably in the man's pocket, he had his clothes examined, and was surprised to find that his supposition was correct. His patient was evidently either a thief, or had found the purse and placed it in his pocket.

Another case is given in which some remarkable things were done by a lightning flash that, on the 18th day of July, 1689, struck the Church of the Saviour, at Languy. The most notable was that it left on a part of the communion cloth markings of some of the words on a card, on which the canon of the mass had been printed.

In both of these cases it is claimed that the photographs were produced by lightning; in the case of the purse, a photograph of the steel monogram; in the case of the church, a photograph of the gilt letters printed on the card resting on the altar cloth. But I think there can be but little doubt that these pictures were produced in an entirely different way. They were simply stains caused by the volatilization or deflagration by electricity of the iron letters of the monogram, or the gilt letters of the card. Such pictures can easily be reproduced at any time as follows. Suppose, as in Fig. 57, a piece of paper is cut by suitable outlining and perforation to represent a portrait of Franklin, and that this paper is placed on a piece of white silk. A sheet of gold leaf is placed on the paper and strips of tin foil A, A′, are placed at the top and bottom as shown; two other pieces of tin foil are placed at right angles to these as at B, B′. If, now, a Leyden-jar discharge be passed between the strips, the gold leaf is volatilized by the intense heat, and the gold vapor leaves a purplish black stain of gold on the silk in the form of the

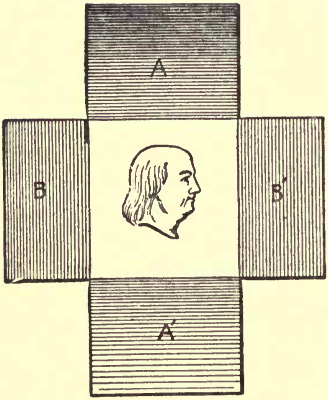


FIG. 57. SILHOUETTE OF FRANKLIN PRODUCED BY ELECTRIC DISCHARGE

design traced on the paper. A similar action probably occurred in the two cases just cited, whereby the monogram was impressed on the man's skin from the vaporization of the iron, and the gilt letters on the printed card were similarly impressed on the silk of the altar cloth.

CHAPTER XXIX

ST. ELMO'S FIRE

According to ancient mythology, Castor and Pollux, the sons of Jupiter and a daughter of man, were highly esteemed by the sailors, who regarded them as their patrons. Castor was celebrated as a horse tamer, and if the stories told of Pollux are true, John L. Sullivan, James Corbett, or Tommy O'Brien might with reason have hesitated to meet him in the ring had they lived in his time; for, Pollux was a great boxer. These demi-gods took part in the renowned expedition of the Argonauts. While on the ship Argo, a storm arose; and the favor of the gods being invoked, two stars immediately appeared on the heads of Castor and Pollux and the danger immediately ceased. For this reason, Castor and Pollux were worshipped by the ancients as the special protectors of seamen.

When the atmosphere is highly charged with electricity, faintly luminous tongues of fire sometimes appear at the ends of bodies in connection with the earth, such as the masts of ships, the points of lances, the branches of trees, etc. When *two* tongues of fire appear on the masts or yards of ships, they are regarded by sailors as foretelling a prosperous voyage; for then it is believed that the spirits of Castor and Pollux have come aboard the vessel and will conduct them in safety to their haven. If, however, only *one* tongue of flame appears disaster is indicated, and shipwreck threatened.

The appearance of these faintly luminous tongues of flame on the ends of the javelins and lances was, in a similar manner, regarded by the ancients as a fortunate omen. Such omens were frequently seen during the ancient wars.

According to Dionysius of Halicarnassus, just before the Romans were about to fight against the Sabines, and were greatly discouraged by reason of their inferior numbers, flames appeared on the long iron points of the lances they had struck in the ground; so, taking heart, they went fearlessly into the fight and succeeded in overcoming their enemies.

As you know, sailors are very superstitious. The legend of Castor and Pollux has been forgotten in most parts of the world, but the appearance of the faintly luminous tongues of flame is still hailed almost everywhere as an evidence of the presence of the spirits of saints who have come to protect the ship. Among a variety of names given to these appearances that of St. Elmo's fire is most commonly employed to-day.

But the phenomenon of St. Elmo's fire can be readily explained without recourse to the supernatural. It is a phenomenon due to the presence of free electricity in the air.

The electricity of the atmosphere does not always pass through the air from charged clouds to neighboring clouds, or to the earth, as in the case of lightning. This discharge frequently takes the shape of the faint tongue of flame now known as *St. Elmo's fire.*

When an insulated conductor containing a large quantity of electricity is discharged by the approach of a blunt earth-connected body, an almost complete discharge occurs by means of a rush of electricity that jumps across the intervening air space, accompanied by a sharp crack or explosion. This is the so-called disruptive discharge, that, as we have seen, constitutes the lightning flash when the charged conductor is a cloud.

If, however, the distance between the two bodies be increased, instead of the discharge taking the form of a single bright flash, it takes the form of a brush of faint light, of a pale blue color, and of so feeble an intensity that it is invisible except in a dark room. This form of electric discharge is known as the *convective*, or *brush discharge.*

Although the brush discharge is not accompanied by the loud report of the disruptive discharge, as in the case of the thunder accompanying the lightning flash, yet at times it is attended by a slight hissing sound. This sound is due to the fact that the discharge is not continuous, but consists of a number of partial discharges rapidly following one another. The hissing, cracking sound, has something of a musical note, which becomes shriller as the distance between the discharging surface and the point to which the charge is directed decreases.

When the electrification increases beyond a given point, or when the area of the earth-connected body is reduced to a mere point, the cracking, hissing sounds disappear, and the brush discharge changes into the glow discharge or the *silent discharge.*

Italian mariners of the Middle Ages regarded the glow of light of the St. Elmo's fire as coming from the body of Christ. Indeed, these tongues of fire are still called by the Portuguese, Corpo Santo, or the Holy Sanctified Body. The belief also exists that the lights are due to the actual presence of the bodies of some of their saints.

Indeed, these luminous tongues have been called by sailors after the names of their various saints. As we have already seen the name most frequently employed to-day is that of St. Elmo. It is not quite certain who this saint was. By some it is believed that he was St. Erasmus, who was generally represented in early art bearing a lighted taper on his head. Others believe that St. Elmo was a Sicilian bishop, who, when dying at sea during a storm, promised the distressed mariners that he would appear on the mast if they were destined to be saved. On his death, the faint tongue of flame was seen on the masthead. As the vessel was saved, the name St. Elmo's fire was given to this appearance.

Don Diegi Columbus, in his description of his father's second voyage, speaks as follows of a number of St. Elmo's fires that were seen:

"On Saturday night (October, 1492), it thundered and rained very much. St. Elmo then showed himself on the foremast with seven lighted tapers; that is, fires were seen which the sailors supposed to be the body of the saint. Immediately many litanies and prayers were sung on board; for seafarers are persuaded that all danger is passed as soon as San Elmo shows himself."

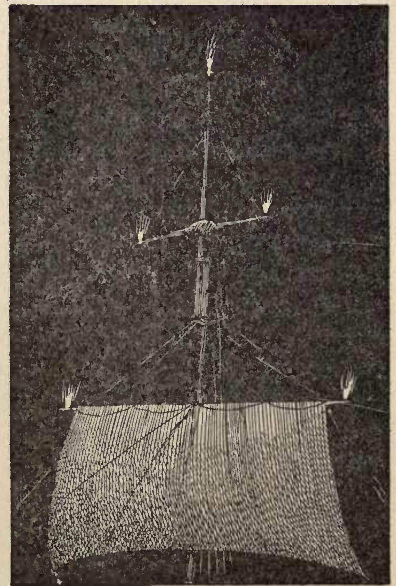


Fig. 58. St. Elmo's Fire on Ship

Referring to the superstition on the part of the sailors as regards the St. Elmo's fires, Lieutenant Bassett, in his book called "Legends and Superstitions of the Sea," says:

"None of the tales told of ghostly shapes or shadowy lands in the ocean world have found so many credulous believers, as those of the ghostly lights that burn about the tops of the ship's spars in the heavy atmosphere preceding a storm, or in the agitated air near its close. Under various names, and connected with numerous legends, this appearance has been the joy or terror of mariners for centuries."

Macaulay, the poet, has also referred to the St. Elmo's fire in his battle of Lake Regulis, as follows:

"Safe comes the ship to haven
Through billows and through gales.
If once the great twin brethren
Sit shining on the sails."

The appearance of St. Elmo's fires on parts of a ship is represented in Fig. 58.

De la Rive gives the following description of a St. Elmo's fire :

"In 1696, at anchor off the Balearic Isles, during very dark weather, accompanied by frightful lightnings and thunders, Forbin relates that they saw on the ship that it was surmounted by more than thirty St. Elmo's fires; there was one in particular, on the top of the vane of the mainmast, which was half a yard in height. A sailor, having climbed to the top of the mast, related that the fire made a particular noise, which, according to the description that he gave of it, appeared to be in every respect similar to that which is made by electricity when it escapes into the air under the influence of a powerful tension. The sailor, having removed the vane, immediately saw the fire leave it to transfer itself to the top of the mast."

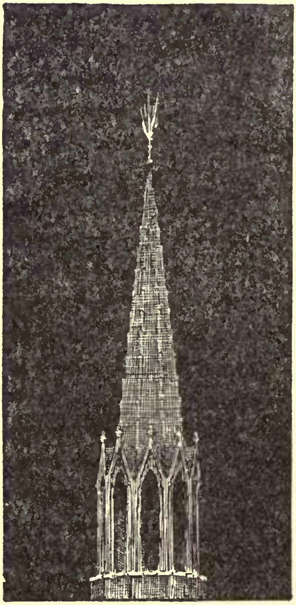


Fig. 59. St. Elmo's Fire on Top of Spire of Notre-Dame

Sometimes St. Elmo's fire is seen on the land, issuing from the points of tall buildings. Such an appearance is represented in Fig. 59, over the top of the spire of Notre-Dame during a thunderstorm on a summer evening.

Strange to say, the St. Elmo's fire sometimes appears around people, as, for example, on the rims of their hats, the ends of their hands, or on the ears and tails of the horses they are riding. This is especially the case during certain luminous storms of rain or snow that occur occasionally in different parts of the world.

Such appearances have been noticed near the summits of high mountains. For example: Bruster relates the case of two English travellers, who, while descending Mt. Etna during a heavy snowstorm, were surprised at observing luminous tongues of flames about their hands and heads.

Although the phenomena of the St. Elmo's fire are apparently of an entirely different character from those of globular lightning, yet the opinion has been expressed that, in some cases, these balls of fire partake of the nature of brush discharges. William Snow Harris, who has given considerable attention to electrical phenomena, especially in connection with the erection of lightning rods on ships, believes that in many cases balls of fire have resulted from the species of brush or glow discharge which precedes the main discharge from a heavily electrified conductor.

CHAPTER XXX

THE AURORA BOREALIS

The free electricity of the atmosphere besides manifesting itself as a bright lightning flash, or as the faintly luminous tongues of flame known as St. Elmo's fire, also produces what is known as the *aurora borealis*, when it occurs in the Northern Hemisphere, and the *aurora australis*, when it occurs in the Southern Hemisphere. Unlike the lightning, or the St. Elmo's fires, this phenomenon is not limited to small portions of the heavens, but often covers a large part of the sky.

The aurora borealis is one of the most impressive of the luminous phenomena of the atmosphere. It takes its name from the Latin word *aurora*, the morning hour; for its light, first seen in the sky near the horizon, is not unlike the light that occurs at daybreak.

This phenomenon assumes a variety of forms. Sometimes huge pillars of fire move rapidly across the sky. At other times, the entire northern heavens are lighted up, as if by a huge storm of luminous snow. Generally, however, a corona, or auroral arch, is seen near the northern horizon, with its highest part immediately under the north magnetic pole of the earth. The height of the arch varies with the latitude, being greater in regions near to the poles of the earth. As the aurora progresses, the arch rises in the heavens and streams of different colored lights, white, red, purple, and sometimes yellow and green, dart up suddenly through the arch, as though coming from the centre of the sphere of which the arch is a segment. These streamers are not motionless, but move with such rapidity that in some parts of the world they are known as the "*merry dancers.*"

The following description of an aurora seen by Captain Peary, during one of his voyages for the discovery of a Northwest Passage, will give an excellent idea of some of the phenomena.

"The aurora began to show itself as soon as it was dark. Innumerable streams of white and yellowish light occupied

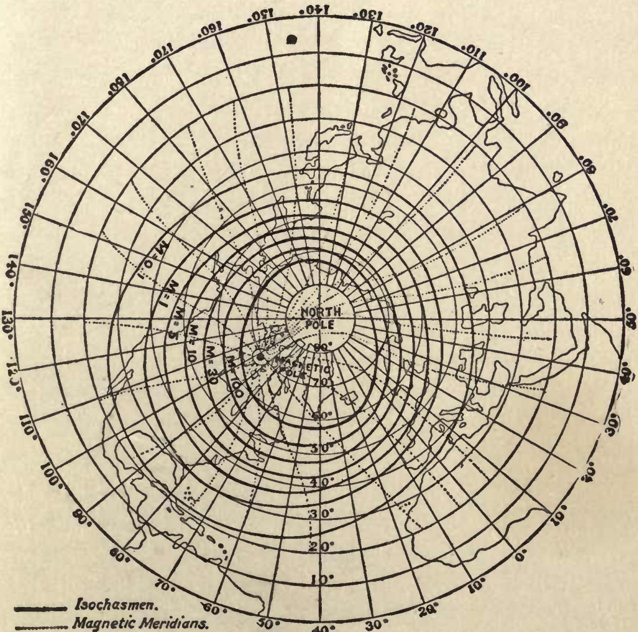


FIG. 60. NORDENSKJÖLD'S CHART OF ISOCHASMIC LINES

the heavens to the southward of the zenith, being much brighter in the southeast, from which it often seemed to emanate. Some of these streams were in right lines, others crooked, and waving in all sorts of irregular figures, moving with inconceivable rapidity in various directions. Among them might frequently be observed shorter bundles of rays, which, moving even with greater velocity than the rest, have acquired the name of 'merry dancers.' In a short time the aurora extended itself over the zenith, about half way down to the northern horizon, but no further, as if there were something in that quarter of the heavens that it did not dare to approach. About this time, however, some long streamers shot up from the horizon in the northwest, but soon disappeared. While the light extended over part of the northern heavens, there were a number of rays assuming a circular or radiated form, near the zenith, and appearing to have a common centre near that point, from which they all diverged. The light of which these were composed appeared to have inconceivably rapid motion in itself, though the form it assumed, and the station it occupied in the heavens, underwent little or no change for perhaps a minute or more. This effect is a common one with the aurora, and puts one in mind, as far as its motion alone is concerned, of a person holding a long ribbon by one end, and giving it an undulatory motion through its whole length, though its general position remains the same. When the streams or bands were crooked, the convolutions took place indifferently, in all directions. The aurora did not continue long to the north of the zenith, but remained as high as that point for more than an hour; after which, on the moon rising, it became more and more faint, and at half-past eleven was no longer visible.

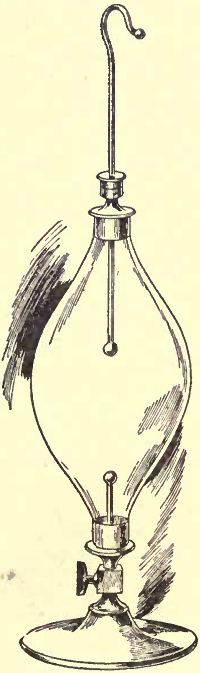


FIG. 61. ELECTRIC EGG

"The color of the light was most frequently yellowish white, sometimes greenish, and once or twice a lilac tinge was remarked, when several strata appeared, as it were, to overlay each other by very rapidly meeting, in which case the light was always increased in intensity."

The aurora presents many different appearances and changes rapidly from time to time. As the under part of the corona, or arch, is dark by contrast with the lighter margin, it looks as though a huge dark orb, covered by a bright outer layer of light, was slowly rising in the northern sky, especially when the streamers dart up through the arch, as though they all came from the centre of a huge globe, of which the corona appears to be a part.

Fig. 62. Discharge in Vacuum

At other times, a series of parallel rays appears as though hanging down from the clouds in the shape of a luminous curtain. This so-called *auroral curtain* really consists of several "curtains," one back of the other, extending across the sky from east to west. This curtain is often colored by horizontal bands bright red on the lower margin, yellow and green in other parts.

The parallel streamers of which the curtain is composed do not remain in a fixed position, but move in a horizontal direction from the right or the left, thus giving the curtain the appearance of a ribbon or flag shaken by the wind. Sometimes, however, an auroral band, consisting of a single streamer, extends across the heavens from east to west.

It is a popular error that auroras are seen most frequently in the immediate neighborhood of the poles. It is true that auroras are very seldom seen in the equatorial regions; indeed, they seldom occur nearer the equator than

40° lat. It is also true that from this point they increase both in number and brilliancy towards each pole. It has, therefore, been assumed that they occur very frequently in the immediate vicinity of the poles. Now, in point of fact, this is not true. Indeed, as can be seen from Fig. 60, which represents a chart of lines called isochasmic lines, or lines connecting places that have the same number of auroras, that the greater number are not found near the poles.

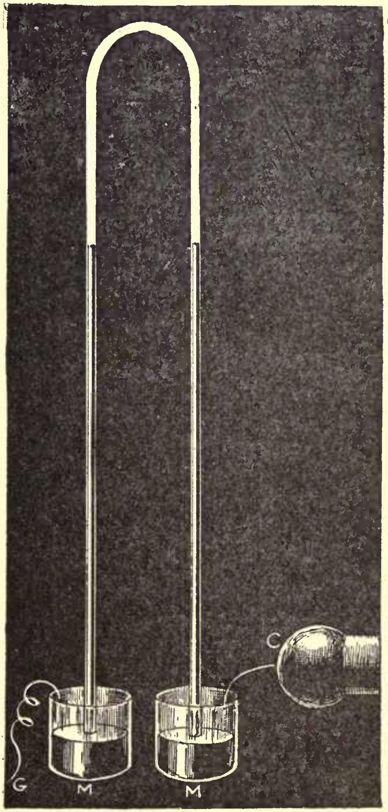


Fig. 63. Luminous Discharge Through Torricellian Vacuum

Nordenskjöld, the Arctic explorer, who passed the winter of 1878–79 in Behring Strait and made a careful study of auroras, declares he found that the earth is continually surrounded by a single or double ring of light he called the aurora glory, the inner edge of which during the years he examined it occupied a height of about twenty-five miles above the earth's surface.

The aurora is due to the passage of electricity through the upper regions of the atmosphere. Air differs, according to its density, in its conducting power for electricity. Near the level of the sea ordinary air is an excellent non-conductor of electricity, so that for an electric discharge to take place through it, a considerable pressure or, as it is technically called, electro-motive force, is necessary. As the atmospheric pressure is decreased, however, the conducting power becomes much better, so that electric charges can pass through it more readily. Take, for example, the egg-shaped glass vessel represented in Fig. 61, and connect it with an air-pump at the same time that an electric discharge is passing. At first, when the pressure of the air is nearly that of the atmosphere, the electric discharge will pass only between the blunt balls, as the usual disruptive spark; and even then, only when the upper sphere is brought near to the lower sphere. As the pressure decreases, a luminous mass of light begins to pass the two knobs even when they are drawn far apart; and, when the vacuum becomes sufficiently low, the entire egg-shaped vessel is filled with a mass of light, reddish at the positive terminal and a deep violet at the negative terminal.

You will remember from the chapter on "Torricelli and His Great Discovery," that, when he filled the long mercury tube with dry mercury and inverted it in a vessel filled with mercury, a vacuous space was left in the upper part of the tube known as the Torricellian vacuum. Now this is a fairly high vacuum. If a long tube be bent into a U-shape, as shown in Fig. 63, and a Torricellian vacuum be established at its upper part, when an electric discharge passes from an electric machine into and out of the mercury cups as shown, the electricity from the machine will pass up the mercury column on the right-hand side of the figure, through the Torricellian vacuum and down through the mercury column on the left, and will then escape to the ground by the wire placed there. When the electric discharge passes through the vacuous spaces, it will produce therein a luminous glow.

As we have seen from these experiments, an electric discharge passing through a vacuum lights it up, or, in other words, becomes a luminous discharge. Now, auroras are caused by the passage of electricity through the extremely rare air of the upper regions, the various colors of the light being due to the different gases in the atmosphere. This can be easily proved by filling glass tubes with different kinds of gases, and leading an electric discharge through the gases by means of wires sealed in the glass. These tubes, which are known as Geissler tubes, need contain only very small quantities of gas to produce the different colors.

CHAPTER XXXI

THE MAGNETISM OF THE ATMOSPHERE

An invisible force existing everywhere in the atmosphere, on the operation of which many phenomena depend, especially the power of the mariners' compass to guide a vessel over the trackless ocean by pointing nearly to the north, is the force of *magnetism*. There is something so mysterious about this force that it has possessed a powerful fascination to the curious in all countries, and during all ages.

A *magnet* is a body that possesses, among other peculiar properties, the power of attracting, or drawing to it, particles of iron or steel and holding them with more or less strength. Like the electric force, magnetism apparently possesses the power of acting at a distance; since it seems to be capable of stretching its invisible fingers across the space between it and a piece of iron and drawing it towards itself. But what is especially curious is that this force appears to be capable of acting, not only through the atmosphere or through spaces that are almost vacuous, but can also act with equal facility through solid earth, or through plates of glass, wooden boards, or other similar solid objects.

You can easily convince yourself that magnetism can act through glass by moving an ordinary magnet over a piece of window glass, when you will find that it attracts small pieces of iron-filings, pens, or iron pins, placed underneath and near the glass; for, as the magnet moves over the glass, the filings, pens and needles, will jump up to the under surface of the glass and, holding on to it, will follow the magnet in a very amusing manner. Magnetism is also capable of passing readily through the human body so as firmly to hold masses of iron placed on the opposite side. In some experiments made with powerful magnets, it was found that when one end, or pole, of a magnet was placed at the back of a man, the magnetism passing through his body firmly held iron spikes against it, on the chest.

The force of magnetism has been known from very early times. It was first observed in an ore of iron, known as *lodestone,* that exists in various parts of the earth. This curious substance is a natural magnet, and possesses, like all magnets, the power of drawing masses of iron to it and then holding on to them with considerable force.

There is no little difference of opinion as to just when the power of lodestones to attract and hold on to iron was first discovered. In the opinion of some this discovery was first made by a shepherd, who, while watching his sheep on Mt. Ida, in Phrygia, was greatly frightened by finding that an invisible force had seized his feet and was holding him fast to the ground.

There was, however, nothing supernatural in what had happened to the shepherd. The shoes on his feet, which were said to have been provided with heavy iron nails, had merely come in contact with a large mass of lodestone and it had held him fast by its attraction.

I am not sure that shoes were provided with nails on their soles in those early days. Indeed, I am somewhat inclined to doubt this story and think another account, sometimes told of the same man, more probable. This was to the effect that it was the iron crook on one end of his shepherd's staff that had been attracted by the lodestone.

It is undoubtedly true that the powerful magnets made to-day would be able to hold a man fast by the iron nails in his shoes. It is by means of magnetic attraction that the heavy trolley cars with their crowds of passengers are drawn rapidly up steep hills. I very much doubt, however, that the shepherd on Mt. Ida found a piece of lodestone sufficiently strong to pin him to the earth as above described; but I repeat the story since it is interesting, is often told when people are speaking of the early knowledge of the ancients about this strange force, and might possibly be true.

I think there can be no doubt that the peculiar power of lodestone was discovered long before any of the above dates. It was not only known to the Chinese at a very much earlier time, but they had even discovered the means for utilizing the strange power it possesses of pointing approximately to the north. It is claimed that there are ancient records in the Chinese language showing that as early as 2600 B. C., and therefore long before the days of the early Greeks or Romans, a Chinese emperor, warring against a rival, employed the magic power of a needle that had the ability to point out the four quarters of the world; for, having routed his enemy, he was able to discover, overtake, and put him to death, under its strange guidance.

But, leaving the early history of magnetism, let us examine an ordinary bar magnet for the purpose of studying some of its peculiarities. We will take for this purpose a simple straight bar magnet. This magnet consists of a bar of hardened steel, which has been magnetized by bringing it into contact with another magnet. Both iron and hard steel can be easily magnetized. Soft iron is more readily magnetized than hardened steel. There is, however, this difference between these two substances: soft iron almost instantly loses its magnetism when it is removed from the body that magnetizes it; hard steel, on the contrary, while difficult to magnetize, retains its magnetism for a practically indefinite time.

That the bar of hardened steel possesses magnetism, can be seen by bringing iron filings near it. But one soon discovers that this power of attracting iron filings is much stronger at some parts of the magnet than at others. It is especially strong at the ends of the bar, at points called the *poles* of the magnet. If the magnet be rolled in iron filings it will be found that the filings collect on the ends of the magnet near its poles, few or none collecting in the central portions. If the magnet be removed and given a sharp tap with a lead pencil, the filings will remain only at the ends of the bar, with practically none between the ends, as shown in Fig. 64.

It is evident, then, that the magnet we have been examining possesses two parts called poles, where the magnetic force appears to be concentrated. Let us examine these poles in order to discover the peculiarities they possess. Our bar magnet has been provided with a cup-shaped piece of polished agate, or other hard · material, so exactly at its centre that it will remain nicely poised on its upright support. This is provided for the purpose of permitting the needle to swing to-and-fro on its upright needle shaped support with a very small amount of friction. If there are no other magnets in its immediate neighborhood, it will, after swinging to-and-fro for awhile, come to rest in a horizontal position, with one of these poles or ends pointing, approximately, to the north of the earth, and with the other pole, of course, pointing, approximately, to the south. Our magnetic bar is now acting as a *magnetic needle*, and has been pulled around, or attracted, by some invisible force, causing it to point approximately to the earth's north and south.

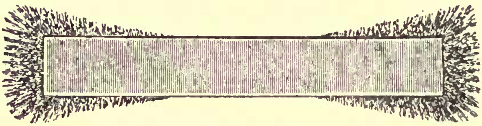


Fig. 64. Distribution of Iron Filings on a Straight Bar Magnet

Now having placed our bar magnet, that is, the magnet represented in Fig. 64, on an upright support, after having removed the magnetic needle to make room for it, we will permit it to swing to-and-fro until it comes to rest. Let us now mark that end which points approximately to the earth's north pole N, and the other end S, and let us agree to call these two points the *north* and *south poles* respectively of the magnet.

Removing the bar magnet, replace the magnetic needle on the stand and, as soon as it has come to rest, pointing approximately north and south, bring the north pole of the bar magnet near to the north pole of the magnetic needle. Instantly, the needle is repelled, or driven away from the north pole of the magnet, and swings around until its south pole approaches it, and then after one or more swings or oscillations comes to rest.

Now, permit the magnetic needle again to come to rest when pointing approximately north and south, and bring the south pole of the bar magnet to the south pole of the needle. The south pole is now repelled and the needle is swung around until the north pole of the needle points to the south pole of the bar magnet.

In like manner it can be shown that when the north pole of the bar magnet is approached to the south pole of the needle, or the south pole of the bar magnet to the north pole of the needle, attraction occurs. Evidently we have ascertained the manner in which the poles of magnets act on one another: like magnet poles repel and unlike magnet poles attract each other.

If you examine Fig. 65, representing the bar magnet with which we have been experimenting, you will notice that a number of lines are represented as passing through the body of the magnet. All of these may be regarded as entering at the end marked S, and coming out of the end marked N. Now, while even with a powerful microscope nothing can be seen either entering or leaving a magnet, it is easy to prove that some such thing exists, and that all around a magnet there is an invisible something by means of which the magnet is able to act across space and draw other magnets towards it or drive them away from it. This invisible force is assumed, though merely for the sake of convenience, to consist of streamings of extremely tenuous or imponderable matter; that is, matter that apparently possesses no weight. The invisible streamings are assumed to act in lines called *lines of magnetic force,* or more simply, *magnetic streamings,* or *magnetic flux.* They surround the magnet for considerable distances from it, and are assumed to come out of one part of the magnet, and, after having passed through the space surrounding the magnet, to return to it at some other part.

The paths of the magnetic streamings in the immediate neighborhood of the magnet can be readily shown by placing a sheet of clean glass over the top of the bar magnet, sprinkling fine iron filings over the glass plate and gently tapping it. Instantly the particles of iron are grouped around the magnet on the surface of the glass in a number of curved lines.

It is assumed that the magnetic flux, or *stream lines,* or more simply the *magnetism,* come out of a magnet at its north pole and enter it at its south pole. Of course, this cannot be proved, for no means have been discovered for showing the direction in which magnetism moves; although we can show, as by means of the iron filings, the path in which it moves. It is convenient, however, to agree that the magnetism comes out of the north poles of the magnet, and, after having passed through the space around it, again enters the magnet at its south pole. When looking at groupings of iron filings on the glass plate above referred to, the magnetic flux passes through the curved path occupied by the particles of iron, so that it comes out of the north pole of the bar magnet and reënters this bar at its south pole.

One of the most important discoveries that have been made respecting our earth is that it acts as a huge magnet, with one of its poles situated in the Northern Hemisphere, at some little distance from the end of its geographical axis, or north pole, and its other pole at a corresponding distance from its geographical south pole. If this is true, and there can hardly be the slightest doubt about it, then out of the earth's magnetic north pole there are continually issuing magnetic streamings that pass everywhere through the earth's atmosphere, both in the regions near its surface and in its upper regions; and, after passing around the earth, through all parts of its atmosphere, it again enters at its south magnetic pole, and, passing through the solid earth again, emerges at its north pole.

For my own part, I think this invisible force of magnetism by far the greatest wonder of the atmosphere. Were we able to see the magnetic flux as it passes in never ceasing streams out of the earth's north magnetic pole, and, after passing through the atmosphere, reënters at the earth's south magnetic pole, we should see a throbbing, pulsating mass of extremely tenuous matter, or of the force or energy which constitutes magnetism, increasing and decreasing, and shifting its position from time to time, not unlike the luminous streamings observable during the progress of an aurora borealis. This would, indeed, be a sight more wonderful than human eyes have ever been permitted to behold. It is to the presence of this force that the power in the magnetic needle in the mariner's compass is due. When a magnetic needle is free to move, it will, under the influence of these strange magnetic streamings, come to rest only when they can pass through it by entering at its south magnetic pole and leaving it at its north magnetic pole.

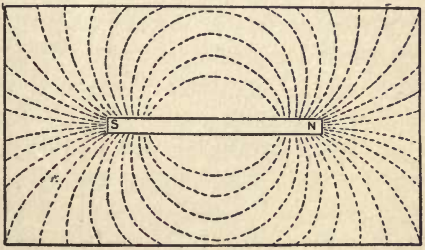


FIG. 65. MAGNETIC FLUX AROUND BAR MAGNET

Of course, no one knows the appearance these magnetic streamings would have in the earth's atmosphere. I imagine, however, that they would be similar to the magnetic groupings of iron filings above referred to, for the oxygen of the air is, like the iron filings, to a certain extent magnetized and would, therefore, arrange itself in regular groupings like them.

It is a mistaken idea that the pole of a magnetic needle invariably points exactly to the geographical north, or that it always points to the same place in the heavens. On the contrary, at by far the greater number of places on the earth the magnet points to the east or west of the true north; and, moreover, the direction in which the needle points suffers gradual changes, not only at different times of the day, at different times of year, and during great cycles of time, but also during the prevalence of what are called magnetic storms. In other words, the compass needle suffers what are called *variations* in its direction. The variations that occur during different hours of the day being called *diurnal variations;* those which occur at different times of the year, *annual variations;* those that occur during cycles of time, *secular variations;* and those that occur during the prevalence of storms, *irregular variations.* The first three are small in amount, and take place slowly, so that the magnetic needle gradually changes the direction in which it is pointing. The irregular variations, however, take place rapidly and present very great changes in the direction in which the compass needle points.

The variations of the magnetic needle prove that the invisible magnetic streamings which pass through all the vast regions of the earth's atmosphere are constantly varying, both in amount and direction; for, since the compass needle only comes to rest when the magnetic streamings enter its south pole and pass out of its north pole, the direction in which the compass needle points must necessarily change with their changes.

If a compass needle is so supported as to be free to swing in a vertical as well as in a horizontal plane, as, for example, represented in Fig. 66, it will come to rest in most parts of the earth with one of its ends dipping on an incline to the earth. This is what is called the *dip* or *inclination* of the magnetic needle.

There are comparatively few places on the earth's surface where the mariner's compass points in a true north and south direction. It is very necessary, therefore, that, in sailing on the ocean in any part of the world, a captain should know exactly how much the magnetic needle should fail to point to the true north at that place; that is, he should know the value of the variations of the magnetic needle at whatever part of the earth his vessel may be.

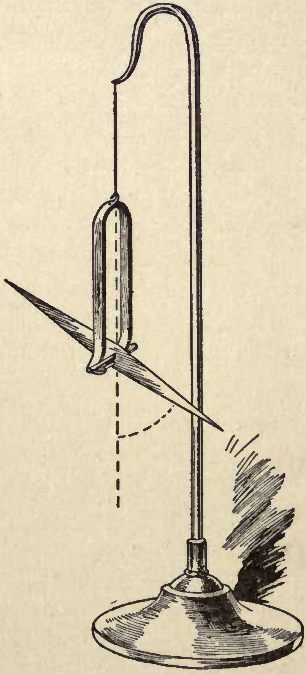


Fig. 66. Dip or Inclination of the Magnetic Needle

It is said that when Columbus was making his great voyage of discovery across the Atlantic towards the New World, he was greatly disturbed by observing that the magnetic needle was apparently losing the mysterious power of guiding him aross the trackless deep. He noticed on the 14th of September, 1492, that, instead of pointing nearly to the north star, the needle pointed about five or six degrees to the westward. Knowing how superstitious the sailors are, he carefully concealed from them this strange change in the guiding power of their needle. But the further he proceeded, the greater became the amount of the deviation of the needle from the north star. At last it became so great that it was noticed by the sailors, and Columbus had no little difficulty in overcoming the fear they expressed that, if the needle were to lose its power of guiding them across the deep, they might never be able to find their way back. At last, however, by pretending to understand thoroughly the cause of the strange change in the needle, Columbus succeeded in calming their fears, for they had confidence in him as a navigator.

I will not attempt to explain to you the cause of the earth's magnetism, but will simply say that it is believed to be due in some way to the passage of an electrical current, either through the earth or through the air. It is known that an electrical current flowing through any conductor invariably produces around it magnetic flux or streamings. It is also known that electric currents are continually passing through different parts of the earth, as well as through different parts of the atmosphere. Indeed, the electric currents in the atmosphere sometimes make their presence known, as we have seen in the aurora borealis.

Now, it is also known that the aurora borealis is especially apt to occur during times when there is unusual activity going on in the sun, such as is manifested by the occurrence of black spots on the sun known as *sun spots*. In the "Wonder Book of Astronomy," I will explain to you that, in accordance with general belief, these spots are due to the presence of great cyclones or storms in the sun's atmosphere. It is a curious fact, however, that the production of magnetic storms on the earth, such as are manifested in the accidental variations of the magnetic needle, occur at the same time that sun spots are unusually prevalent. In other words, that, in a manner which is not exactly understood, when a huge cyclonic storm is raging in the sun's atmosphere, it is accompanied by another storm in the invisible magnetic streamings that pass through the earth's atmosphere.

In the past, ignorant people were quite willing to credit the force of magnetism with very great power. For example, in that charming book called the "Arabian Nights," which I trust you have read, and which, if you have not done so

I would advise you to read at the first opportunity—a story is told in the "Third Royal Calendar," of the wonderful adventures of Prince Agib, in which we are told of a lodestone mountain whose magnetic power draws all the nails out of passing vessels and thus causes their destruction.

CHAPTER XXXII

OZONE

I suppose there is not one who reads this book, no matter how young he or she may be, who does not know the meaning of the three gilded balls that are hung up in front of a dingy shop in some street in the city in which you live. Such a shop is generally provided not only with an entrance on the street where one can go in full view of the passers-by, but also with a side entrance where those who have not yet become hardened by frequent visits, may enter. As you know, the balls are intended to locate a pawnbroker's shop or, as some people called it, "my uncle's." I trust that none of you, or any of those for whom you care, will ever have to be obliged to borrow money on pledged articles at the high rates usually demanded in such places.

It may interest you to know that the three gilded balls are the coat of arms of the celebrated Medici family. Pawnbrokers' shops had their beginning in 31 B. C., when a fund was established by Augustus Cæsar to be employed for lending money to persons on pledge. What might properly be called pawnbrokers were established in Italy at Perugia, in 1462, thirty years before the discovery of America by Columbus.

You are doubtless desirous of knowing what pawn-brokers' shops and their three gilded balls have to do with the work on the "Wonders of the Atmosphere." I have chosen this method of introducing this chapter on ozone because I wish to impress a certain fact on your mind.

You will remember that the two principal gaseous ingredients of the atmosphere are nitrogen and oxygen, two elementary substances that are invariably found, in nearly the same relative proportions, in the lower layers of the atmosphere near the sea level, as well as in those parts of the higher regions that have been reached by man. You will remember, too, that these ingredients possess properties that are in marked contrast to each other; the oxygen readily entering into combination with nearly all the other chemical elements, while the nitrogen refuses to have anything to do with them, entering into combination with few of them, and then only under rather unusual conditions.

Ozone is a curious modification of the oxygen of the atmosphere which possesses a very unusual power of chemical activity. In order that you may understand this modification I must give you a little insight into that curious state or condition of matter known as the *allotropic state.*

A number of elementary substances possess the curious power, while unmixed with any other elements, of exhibiting several entirely different kinds of properties. For example, one form of perfectly pure carbon is known as *charcoal;* another form, as graphite or *plumbago,* the material employed for lead pencils; and still another form, as the *diamond.* All these substances consist of chemically pure carbon; and yet how different are their physical properties! Both charcoal and plumbago are of a deep black color, absorbing nearly all the light that falls on them, while the diamond is one of the most brilliant of gems. They differ, too, in their hardness. Charcoal is only fairly hard and plumbago is so soft that it can be readily scratched with the finger nail, and can be broken into fragments by the slight force that is required to draw it over a sheet of paper; for the tracings, or markings it leaves on the paper consist of fragments torn from it as it moves over the surface. The diamond, on the other hand, is so hard that there are very few substances that can cut or scratch it. There was a time when it was believed that the diamond was the hardest of all substances, but recently a few chemical compounds have been discovered produced in the great heat of the electric furnace, that are harder than the diamond. Now these three different forms of carbon are excellent examples of its allotropic state or condition and of the element.

Oxygen, like carbon, is also capable of assuming an allotropic state or condition, namely, as ozone; so that you need not be surprised when I tell you that ozone, or allotropic oxygen, possesses properties that are quite distinct from ordinary oxygen.

For the sake of convenience, chemists still regard atoms as consisting of exceedingly small ultimate particles; and in representing them by symbols, generally by the initial of their names, one atom of oxygen is represented by an O. Now, all the atoms of the different elements act as if they possessed what are called bonds, or places where they attract one another and become united. Some elements, such as hydrogen, have but a single bond; others have two bonds, such as oxygen; and still others have three, four, five, six, etc., bonds.

It has been observed that when any element has just been liberated from combination with another element, and, therefore, has its bonds open or free, or is in what is called the *nascent state*, it possesses properties somewhat different from what it possesses after it has been for some time free. For it seems that as soon as an element, say, for example, oxygen with free or open bonds is mixed with other atoms with free or open bonds, it is apt to enter into combination with them.

If it troubles you to understand this matter, it may be of aid if you regard the bonds possessed by atoms as hands, by which they reach out and take hold of other atoms. In this sense oxygen may be regarded as a two-handed person; that is, it has two hands by which it can unite with the bonds of other elements.

Now when oxygen is in a nascent state it may be called *atomic oxygen*, and may be represented as in Fig. 67.

Since its bonds are free, if it finds no other element with which to combine, it will combine with other atoms of oxygen; and since it has two hands, you can see the two atoms of oxygen might combine with each other as in Fig. 68.

FIG. 67. ATOMIC OR NASCENT OXYGEN

Oxygen so combined constitutes what is known as *molecular oxygen;* a molecule differing from a free atom in that such an atom necessarily has its bonds open or free, while a molecule has its bonds always closed by combination with other atoms. Ordinary oxygen when not in the nascent state is supposed to consist of molecular oxygen.

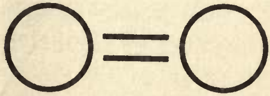


FIG. 68. MOLECULAR OXYGEN

Let us now come again to the three gilded balls of the pawnbroker. The atoms of oxygen are capable of combining with one another in another way. It is possible for three atoms of oxygen to combine as represented in Fig. 69.

Here each atom of oxygen takes hold of one of the bonds of another atom, thus making a closed chain consisting of three atoms.

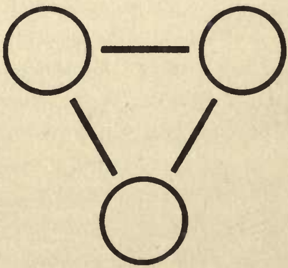


FIG. 69. OZONE OR TRI-ATOMIC OXYGEN

Let us now see what properties are possessed by this curious modification of oxygen. Let us also inquire as to the manner of its discovery, and study some of the effects that are produced by its presence in the atmosphere.

As you know, the two balls of the pawnbroker are placed below a single ball. This, perhaps, is based on a sad experience that the balls suggest to the party who has before left something in pledge, that the chances are "two to one that it will ever be yours again."

If you have ever seen a large electrical machine in operation; or have ever been near a large Ruhmkorff coil when it is pouring torrents of electric sparks through the air; or have ever been in a room where a great number of arc electric lights are burning, you may have noticed a peculiar odor, and possibly experienced an irritation of the throat on breathing the air. If you have, you have personally experienced some of the effects of the peculiar modification of oxygen known as ozone. In the same manner it is ozone that causes the peculiar odor produced by the passage of a lightning flash through the air, often described as a sulphurous smell. In point of fact, the odor of ozone is quite different from a sulphurous smell, as you would readily observe were the opportunity afforded you of smelling these two substances successively.

It appears that the first to notice the smell of ozone was Von Marum, in 1783. This physicist observed that when electric sparks were passed through a tube containing oxygen gas, the gas thereby acquired both a peculiar odor and unusual oxidizing powers. Shortly afterwards Tiberius Cavallo noticed that a peculiar smell accompanied the chemical decomposition of the water by an electric current. He called the air, or gas thus produced *aura electrica*, or electrified air, and observed that it had a purifying effect on decomposing animal or vegetable matters. Indeed, he actually employed it as a disinfectant for bad smelling ulcers.

In 1826, Dr. John Davy recognized the existence of this material in the atmosphere, described how it could be prepared, and suggested a chemical test for its detection.

Nothing was done as regards this substance until 1840, when Schönbein, the Swiss chemist, observed the peculiar smell possessed by the oxygen that was liberated from water during its electrical decomposition. He recognized that this material possessed properties similar to the aura electrica of Cavallo, and proposed for it the name of *ozone* from a Greek word meaning to emit a disagreeable smell.

Schönbein published a paper describing this discovery that gave rise to considerable discussion as to the true nature of the new substance. He thought at first it was a new element of the same class as bromine or chlorine. He afterwards thought it might be one of the substances of which he thought nitrogen consisted. He finally concluded that it was a combination of hydrogen and oxygen. All of these views were shown to be erroneous, and it was finally proved that ozone is only an allotropic modification of oxygen.

Ozone possesses, in general, properties that are similar to those of oxygen. But it possesses these properties in so much more powerful a degree that, at first sight, it appears to be a quite different substance.

Ozone is a strong oxidizing agent and is capable of decomposing iodide of potassium; that is, of setting free the iodine and the potassium. Ozone rapidly oxidizes ammonia and changes it into nitric acid. Indeed, it is so strong an oxidizing agent that it is capable of acting as a *powerful bleacher*. When properly administered it is able to cure, or at least markedly relieve, certain diseased conditions of the body, such as tuberculosis, rheumatism, scrofula, etc. Indeed, it possesses so many valuable properties that various endeavors have been made to produce it in large quantities directly from the air. These processes are chemical, electrochemical, or electrical.

The electrical process for producing ozone consists in passing a series of electric sparks through air. In order to produce the greatest amount of ozone in this way, the air that is acted on by the discharge is separated from the surrounding air by a glass tube through which the discharge passes.

Ozone is not only of use as a powerful *disinfectant*, but it is also a powerful *germicide;* that is, it possesses the power of destroying microscopic germs that produce deadly diseases. For this reason ozone has been employed for the purification of water, or what may more correctly be called the *sterilization* of water. Water is first deprived of its suspended or mechanical impurities by filtration, and is then subjected to ozone, which rapidly destroys all its microorganisms.

I will merely point out some valuable chemical processes in which ozone is employed, such, for example, as the synthetic production of indigo, and in the artificial production of vanilla extract. It is almost invariably present in the atmosphere, but how atmospheric ozone has been produced is not known exactly. Probably, however, while it may be produced in a variety of ways, it is principally produced by the passage of electrical discharges through the air.

Despite the exceedingly small quantities of ozone found in the air, its presence there is of very great value from its powerful purifying action, and from its ability to destroy the microscopic organisms that produce miasmatic and contagious diseases. Although, when pure, ozone possesses a very disagreeable odor, yet in small quantities it imparts to the air a pleasant fragrance. The presence of ozone gives to the air at the seashore, as well as in the mountains, its health-giving properties. It is, probably, the ozone of the air at these localities that gives such powerful aid towards the recovery of invalids by the destruction of disease germs.

Ozone is now regarded as so important a constituent of the air that meteorological observations now generally include tests for its presence in the atmosphere.

The test for the presence of ozone in the air is based on the fact that free iodine is capable of imparting a deep blue color to a starch solution. Test paper for the detection of ozone is prepared by steeping an unglazed paper in a mixture consisting of a small quantity of iodide of potassium boiled in starch and water. This paper, cut into strips and dried in a closed room, when exposed to air in which ozone is present, is colored a deep blue; for the ozone, setting free the iodine in the paper, permits it to act on the starch, producing its characteristic stain.

I have no doubt that most, if not all of my readers know just what is meant by *malarial air*. This is air that is poisoned by exhalation from decaying animal, or vegetable matters. In moist or swampy districts, where the water, instead of draining off the surface, stagnates and breeds enormous quantities of bacteria and other microscopic organisms, which are capable, when they find a proper lodgment in the body, of producing malaria and other diseases. Possibly you may know some of these diseases better as *chills and fever*, or *break-bone fever*. They are attended by repeated chillings of the body, in which the patient shakes as if from cold, and desires to be covered with thick clothes. Then, suddenly, the chill changes to a burning fever. During these diseases a tired feeling comes over the patient as if his bones had suddenly greatly increased in weight.

Malarial districts are especially dangerous towards the close of a very hot day, shortly after the sun has set. Such districts are common on the low, marshy shore-lands of the Mediterranean, especially in portions of Italy.

The higher the temperature of the air, the greater the danger from malarial districts; for the disease germs multiply rapidly in the hot stagnant water of the marshes during the heat of summer. Poisonous or mephitic gases laden with disease germs pass into the air and produce fevers and diseases of various kinds commonly known as *miasmatic, contagious*, and *infectious diseases*.

The low, tropical coasts of different parts of the world are generally exceedingly unhealthful. Some of the coasts of Africa are so unhealthy that it is dangerous for white people to remain in them for even a short time; so that those who wish to visit the interior of the continent are obliged to pass rapidly through the low coast districts to the invigorating atmosphere in the higher plateaus and mountain regions near the coast.

The reason that the air in the higher regions is so healthful and invigorating, although but a few miles from the lower miasmatic and disease laden air, is that it is free from disease germs. This freedom is due especially to the fact that such germs as may have reached these elevations have probably been killed by the presence of free ozone in the air.

CHAPTER XXXIII

CONCLUSION

We have studied together, and, I trust not unprofitably, some of the Wonders of the Atmosphere. I have shown you that in the great ocean of air in which we spend all our lives, many wonderful things are constantly occurring, which, although plain to be seen, are apt to remain unseen until attention is called to them.

You must not suppose that we have by any means discussed all the wonders of the atmosphere; for there are many strictly atmospheric phenomena that we have been obliged to omit for want of space; others that we have purposely omitted because they can, more properly, be discussed in some of the other Wonder Books which are to be included in this series. It might be well, however, in this chapter to mention briefly some of the topics that we shall, perhaps, discuss more fully elsewhere.

There are many reasons for believing that the composition and general character of our atmosphere have not undergone any decided change during the past five or six hundred thousand years. Even at the beginning of this time there were, in all probability, the same relative proportions of inert nitrogen and active oxygen in the earth's atmosphere. There was probably, also, practically the same proportion of carbonic acid gas, as well as some of the rarer gaseous elements, or compounds. There were the same differences of temperature produced by the sun's heat, so that the atmosphere exhibited similar changes of temperature to those which now characterize it, and was tossed about either by the gentle breezes that gradually moved it from place to place, or was furiously lashed by the great tornadoes, hurricanes, or cyclones that are now common in certain parts of the world. Its invisible vapor was, then as now, deposited as dew on the surfaces of the cooled bodies with which it came in contact, or became visible as fogs, or clouds, differing in no respect in their forms from those which can now be seen at different times in different parts of the sky. It had the same rainfalls, the same hail, and snowstorms that it now has. It was at some times more densely filled than at others with floating dust particles, caused either by the action of the wind on the sands of deserts, or by the finer volcanic dust thrown out of the craters of volcanoes.

So, too, the atmosphere of this comparatively recent geological time had the same thunderstorms, and presented the same optical phenomena as now. There were necessarily terrific lightning flashes, and thunder peals reverberated through the air, though heard only by the animal inhabitants of the world; for this time was before the creation of man. There were the same gorgeous sunsets, the sky had the same blue color, and when the storm had passed, the same rainbow was placed in the sky.

There were, too, the same so-called prodigies. At times, the sun appeared to multiply himself, so that there seemed a number of suns in the sky; and the same multiplied appearances were produced about the moon. So, too, the images of distant objects seen out of their true position were brought into the full view of the animals of the earth by means of extraordinary refraction of light.

There must, however, have been some differences in the earth's atmosphere, even during this comparatively recent time; for, whenever there were unusually great changes in temperature, such as existed in the entire Northern Hemisphere during a geological period known as the *Glacial Age*, the quantity of water vapor in the air must have differed from the quantity now present. If we go back far enough, through the millions of years, until we come to the time when the earth's climate was much hotter than it now is, the differences of temperature would necessarily have caused the movements of winds to be far more violent than those of the present time. During the Carboniferous Age, when great beds of coal were deposited, since all this carbon must have existed in the air in the form of carbonic acid gas, there was then, of course, a greater proportion of carbonic acid gas in the atmosphere.

But, even during these earlier geological periods, the earth apparently possessed in many respects an atmosphere not very unlike that which exists to-day. There was the same sunlight, as would appear from the fact that some of the earliest fossil animals were provided by God with eyes, and this would hardly have been the case if there had been no light for the vision of such eyes.

Going back further, to the time when the earth had just been separated from the nebulous sun, the earth's atmosphere was indeed very different from what it is to-day. Assuming LaPlace's Nebular Hypothesis to be correct, which teaches that all the planets of the solar system were once collected together in a mass of highly heated nebulous matter, and that they were gradually separated from the sun, we may properly regard all the earth at that time as consisting of one huge atmosphere; for it was all a highly heated gaseous matter from its centre to its surface. At this early time, all the materials that now form the earth were in the form of incandescent gases or vapors; or the whole earth consisted of a gaseous or vaporous atmosphere, and it must have required millions upon millions of years before this immense mass liquefied, and gradually solidified, to form the now solid earth.

Our atmosphere, therefore, has passed through a series of gradual changes whereby more and more of the materials of which it was originally composed have, by loss of heat, been first liquefied and subsequently solidified, and thus collected in the earth's solid mass. It has been only those materials which could exist in the gaseous state at very low temperatures that have remained permanently in its atmosphere. In the case of such materials as water, that are capable of being easily vaporized, such exist alternately in the atmosphere as invisible vapor, or on the earth as water, ice, or snow.

The early condition of our atmosphere was probably not unlike that which now exists in the atmosphere of the sun. Here, as the spectroscope shows us, there are permanent gases like hydrogen, but so highly heated as to be luminous. In addition there are the vapors of various metallic substances, so that no life is possible in the atmosphere of the sun, at least no life possessing the characteristics of any known forms of life.

Since we have endeavored thus to trace the atmospheric conditions of the earth, from what they are at present to what they were millions upon millions of years ago, when the earth was very, very, young, you may inquire what will probably be the condition of the atmosphere millions of years from now. The question is a fair one, and one, too, that I think can be correctly answered. Our atmosphere will gradually disappear and become a thing of the past. But this will occur at a time so very remote that it need occasion no alarm. There are various causes now acting which admit the supposition of such a disappearance. Let me point out to you some of the ways by which this disappearance might be brought about.

In the first place the oxygen of the air, on account of its powerful oxidizing powers, tends to enter into combination with various substances, and thus become converted into solid oxides. In a similar way the carbonic acid of the air may be greatly decreased in amount by entering into combination with various oxides or gaseous substances, thus producing salts called carbonate. The nitrogen of the air may also be to a great extent absorbed by solid substances.

Since, however, nitrogen possesses very weak chemical properties, it would seem as if the earth might always be left provided with an atmosphere of nitrogen. This might be true were there not another very powerful cause constantly tending to diminish the earth's atmosphere.

When a body is thrown vertically upwards from the earth's surface, the distance to which it will rise depends on the amount of the projectile force; or, in other words, on its velocity upon leaving the earth's surface. The earth is all the time attracting or drawing the object towards it, so that its upward motion becomes slower and slower, until at last it remains stationary for a very short time, and then begins to fall back again to the earth. If, however, the force with which it is thrown from the earth is sufficiently great, it might rise so high in the air that the attraction which the earth exerts to draw it back, would be less than the attraction of the moon, or some other heavenly body, to draw it towards itself.

Now it can be shown in a way I will not now attempt to explain to you, since it is a somewhat abstruse circumstance connected with the kinetic theory of gases and radio-activity, that both the molecules in the atmosphere and the fragments of atoms of its elementary gases are, in some regions of the atmosphere, moving with velocities quite rapid enough to cause them, when moving in directions from the earth, to fly off into space never again to return to the earth, and this may ultimately occur in the case of our earth, thus leaving it without any atmosphere at all.

There is every reason for believing that the moon was once a part of the earth, and was separated from it when the earth had a rapidity of rotation on its axis sufficiently powerful to throw off a mass of matter with a velocity so great as to prevent its return. There must, therefore, have been carried off with it the same kind of atmosphere that the earth possesses. Therefore, at one time of its existence, the atmosphere of the moon, in all probability, did not differ very greatly from that of the earth.

Now, since the moon is a much smaller body than the earth, it has cooled more rapidly than the earth; so that the condition of things now existing on its surface is such as the earth will probably have many millions of years from the present time. It has been shown by numerous observations that the moon has almost no atmosphere. Indeed, until a comparatively short time ago, it was thought to have no atmosphere at all. It is believed, now, however, that it does possess some traces of atmosphere, consisting, probably, of a small quantity of water vapor and carbonic acid gas; and that this, in the very distant future, may be the composition of the earth's atmosphere.

THE END