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Nature's Miracles

Familiar Talks on Science

BY

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Vol. I

World-Building and Life

Earth, Air, and Water

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INTRODUCTION.

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Dear Reader: Please look through this "Introduction" before beginning with the regular chapters. It is always well to know the object, aim, and mode of treatment of a book before reading it, so as to be able to look at it from the author's view-point.

First: A word about the title—"Nature's Miracles." Some may claim that it is unscientific to speak of the operations of nature as "miracles." But the point of the title lies in the paradox of finding so many wonderful things—as wonderful as any miracle that was ever recorded—subservient to the rule of law.

"But," you say, "a miracle does not come under any rule of law."

Ah! are you sure of that? It is true that we may not understand the law that the so-called miracle comes under, but the Author of all natural law does. We do not pretend to dispute but that the

Power that made nature's laws can change them if He sees fit; but we cannot believe that He will ever see fit. It would destroy all order and harmony, all advancement in science and knowledge of [Pg vi] God's works, not to be able to rely implicitly upon the laws of nature as consistent and continuous.

In putting out these little volumes, it is not to be understood that the subjects treated will be more than touched upon, at the most salient points. To do much more would require volumes of immense size, and life would be too short for me to write or for you to read them.

Again: these volumes are "familiar talks." The Author wishes to sit down with you—so to speak—and not hold you at arm's length.

It will be his aim to use the language of common life and to avoid all technical names so far as possible, or, when they are necessary, to explain their meaning. The object is to reach the thousands of readers who have not and cannot have the advantages of a scientific education, but who can by this means get at least a rudimentary idea of some of the natural laws with which they are coming in contact every hour, and through which the inner man has constant communication with the outer world. It may be, too, that many young students will be helped by these plain general views of topics which their text-books will give them in detail.

A knowledge of the real things in the objective world about us and the laws that govern them in their inter-relations is of practical value to every man, whatever his calling may be. Not only will [Pg vii] it be of value practically, but it will also be a constant source of interest and pleasure. Man is so constituted that he must have something to be interested in, and if he has no resources within himself he looks elsewhere, and often to his hurt, mentally, morally, or otherwise. If he could have an interest awakened in him for the study and contemplation of the natural world he would then have a book to read that is always open, always fresh, always new. He is dealing with facts and not theory, except as he uses theory for getting at facts.

A man who is all theory is like "a rudderless ship on a shoreless sea." All he really knows is that he is afloat, and if he lands at all it is likely to be in an insane asylum. The mind, in order to keep its balance, must have the solid foundation of real things. Theories and speculations may be indulged in with safety only so long as they are based on facts that we can go back to at all times and know that we are on solid ground.

It is the desire and aim of all good men to make their nation a truly great people, with a civilization the highest possible. The character of all kinds of growth is largely determined by the character of the material upon which it feeds. The study of natural law can never be harmful, but is always beneficial, for the student is then working in harmony with law. It is the violation of law [Pg viii] that makes all the trouble in the world—whether physical, moral, or social. When we speak of natural law we do not confine ourselves to what is commonly known as chemistry and physics, and the laws that govern the material world, but include as well the laws of our own being, as intellectual and spiritual units. For all law, physical, intellectual, and spiritual, is in a sense natural.

All departments of science are simply branches of one great science, and all phases of human activity are touched by it. The preacher is a better preacher, the doctor a better doctor, the lawyer a better lawyer, the editor a better editor, the business man a better merchant, and the mechanic a better workman, if they follow scientific methods. Indeed, any man will be a better husband, father, and citizen, if he has some trustworthy knowledge of the laws under which this great universe, down to his own little part of it, lives, moves, and has its being.

[Pg 1]

NATURE'S MIRACLES.

EARTH.

CHAPTER I.

WORLD-BUILDING AND LIFE.

"In the beginning God created the heaven and the earth. And the earth was without form, and void."

Whatever our speculations may be in regard to a "beginning," and when it was, it is written in the rocks, that, like the animals and plants upon its surface, the earth itself grew; that for countless ages, measured by years that no man can number, the earth has been gradually assuming its present form and composition, and that the processes of growth and decay are active every hour.

The science that deals with the formations and stratifications that are found on the earth and under the earth, and all the forces that have been and are now active in their formation, is called Geology (earth science). It is a science about which little is known by the average individual, and [Pg 2] yet it is one of transcendent interest, from the study of which the lover of nature can obtain a vast amount of profit and pleasure. When the uncultured man sees a stone in the road it tells him no story other than the fact that he sees a stone and that it would better be removed; and all the satisfaction he gets out of it is in the thought that he has saved some unlucky wagon wheel from being wrenched or broken. The scientist looking at the same stone perhaps will stop, and with a hammer break it open, when the newly exposed faces of the rock will have written upon them a history that is as real to him as the printed page. He is carried back to a far-off time, where he sees the processes and forces at work that have formed this stone and made it what it is, not only in its outward form, but in its constitution, down to its molecules and atoms. (The word "atom" is used in chemistry to mean the smallest particle of an elementary substance that will combine with the atoms of another substance to form new compounds of matter. And molecules are made up of atoms.) The scientist looking at this stone sees in it not only that mechanical and chemical agencies have cooperated in the work of its formation, but that animal life itself may have been the chief agency in bringing the materials together and giving form to the peculiar architecture employed in its formation. If it is a piece of limestone this latter statement will be eminently true. [Pg 3]

Here is a powerful motive for the study of physical science. It is not to be expected, nor is it possible, that every individual can be a scientist in the strict sense of the word, but it is possible for everyone of ordinary intelligence to become familiar with the salient facts of science, if only a small portion of the time that is now devoted to the reading of literature that is rather harmful than helpful be spent in studying the phenomena and works of nature.

The acquirement of such knowledge would furnish every individual with a constant source of instructive amusement that would never lose its interest. He would not be dependent every hour upon people and things outside of himself; because he would carry about with him inexhaustible sources of instruction and pleasure that would furnish him continual and helpful diversion and save him from a thousand morbid tendencies that are always ready to seize upon an unemployed mind. There are many men and women in the insane asylum to-day for the simple reason that they have not made intelligent use of the mental powers that nature has endowed them with.

Sermons are not always preached from pulpits. They are written in the rocks and on the flowers [Pg 4] of the field and the trees of the forest.

Let us then look a little at the underground foundation of all this beautiful earth. And before attempting that, the question may arise in some minds how we know what is so deep down under the surface. Fortunately this is a question very easily answered. At some period after the rocks were formed the crust of the earth was broken by volcanic eruptions at various places and times, and turned up, as in the formation of mountains, so that the edges of the various stratifications of the rocks, from those near the surface down to the lowest rocks, are exposed to view. Another means of knowing what the various formations are has been by borings of deep wells. These borings, however, are only confirmatory of what was well known before through the upheavals that are plentiful in all parts of the world. There is abundant evidence that all of the rocks and all of the strata of every name and nature (except perhaps igneous rocks) were originally laid down in water. This is evidenced not only by the stratifications themselves, but by the evidences of sea-life everywhere present in the earth's crust. Before the upheavals in the earth's crust began, the whole surface of the globe was a great ocean of hot water. The substances of which the rocks [Pg 5] were formed were undoubtedly held in suspension in the air and in the water, and by a gradual process were deposited in the bottom of the ocean in layers, forming rocks of various kinds, according to the nature of the substance deposited. Gradually the crust of the earth was built up until it acquired a certain thickness; when, either from shrinkage under the crust a great void was formed until it could not sustain its own weight, or the pressure caused by confined gases and molten matter produced an upheaval which broke the crust of the earth outward, causing great wrinkles that we call mountain ranges. Undoubtedly both forces were active in producing these results. When the gases and molten matter had escaped through the rifts in the rocks caused by the upheaval there must have been great voids formed that were filled up by the shrinkage of the earth, causing much irregularity in its surface.

In some places there were enormous elevations, and in others correspondingly deep depressions. The water that before was evenly distributed over the surface of the globe, after the upheavals ran off into the lower levels, filling up the great valleys, forming the seas, and leaving about one-third of the land surface uncovered. It must not be supposed, however, that the appearance of the land was caused by one grand movement or upheaval, but that it has been going on in [Pg 6] successive stages through long ages of time. This is clearly evidenced by the rock formations. The deposition of rock strata is still active in the bottoms of the oceans, although not to the same degree as in former times. When the upheaval took place the old stratifications were thrown out of level, but the new ones that were then formed remained in a level position until they were in their turn disturbed by some subsequent upheaval.

The laws of gravitation would tend to precipitate the matter held in suspension by the water straight down to the bottom, toward the center of the earth, so that the plane of these stratifications would tend to be parallel to the surface of the water, that is horizontal, until disturbed. Then they would be tilted in many directions. Hence it will be easily seen why the seams in the rocks, especially in and near mountainous regions, do not lie in a horizontal position after an upheaval, but are found standing at all angles, up to a perpendicular.

Viewed from this standpoint, the solid portion of the old world has gone all to pieces. Wherever there is a chain of mountains it marks a breakage in the earth's crust, and these mountains are not all on the land, but extend under the seas so deeply that they are unable to lift their heads above the surface of the water. The earth is no longer round, except in general outline, but [Pg 7] broken up into all sorts of shapes that give the varied conditions of landscape that we find whichever way we turn.

There are but few volcanoes that are active in this age, while in former times they extended for thousands of miles. We still have occasional earthquakes, but undoubtedly they are very slight as compared with those that shook the earth millions of years ago.

If, now, we study the constitution of the earth's crust so far as it has yet been penetrated, we find it divided up into periods called Primary, Secondary, and Tertiary. The primary period reaches down to the line where the lowest forms of animal fossils begin to be found. This is called the "Paleozoic" period, which means the period of "ancient life." From here let us first go downward. Immediately under this lies a stratum of "Metamorphic" rocks. To metamorphose is to change; and metamorphic rocks are those which have been changed by heat or pressure from their original formation. This class of rocks lie on top of what are called "Igneous" rocks, which means that they have been formed by or subjected to heat. All lava-formed rocks are igneous. They are unstratified,—not in layers or strata, but in a formless mass,—and in this they differ from water-formed rocks. [Pg 8]

If there is a molten center to the earth these igneous rocks are undoubtedly the offspring of this great internal furnace. The metamorphic rocks were primarily igneous and are changed somewhat in their structure by the lapse of time. For instance, marble is a metamorphic limestone. The difference between common limestone and marble is in its molecular structure—the way in which its smallest particles are put together. They are both carbonates of lime. But the marble is made up of little crystals and will take a polish, while ordinary uncrystallized limestone will not. The igneous rocks are chiefly granite; and granite is formed of orthoclase-feldspar, mica, and quartz. (The word "orthoclase" means straight fracture, and the orthoclase-feldspar has two lines of cleavage at right angles to each other.) This is the ordinary composition of granite, but there are a great many variations, chiefly as to color and proportions of the ingredients named.

The igneous rocks, then, are the lowest of all; then come the metamorphic rocks; and as before stated, on top of metamorphic rock begins the first evidence of life in its lowest form. The Paleozoic (ancient life) or Primary period is made up of a number of subdivisions. The first and oldest division is called the "Silurian" age, which is underlaid by the metamorphic rocks and overlaid by the rocks of the Devonian period. It is called Silurian, from the name of a kind of fish, [Pg 9] fossils of which are found in the rocks of this age, which are distinguished for the absence of land-plant fossils and vertebrate animals.

In the Silurian strata are found limestones, slate, flagstones, shales, etc. On top of the Silurian begins the "Devonian" age, in which is found the old red sandstone, as well as limestone and slate; and here begin to be found the fossils of land-plants. On top of the Devonian lies the "Carboniferous" series, which complete the series of the primary period. In the lower part of this stratum is found carboniferous limestone, which is overlaid by a kind of stone called millstone grit, and on top of this lie the true carboniferous strata or coal-bearing measures. In the coal strata are found the first reptile fossils.

On top of the coal measures begins the Secondary period, or "Mesozoic" (middle life). This period is distinguished for the great development of reptiles, and is called the "age of reptiles." In this age occur the first traces of mammals, and birds, and fishes with bony skeletons. Among plants we find here the first evidence of palms. The formation is chiefly chalk, sandstones, clays, limestone, etc. We now come to the last or "Tertiary" period, which brings us to the top earth. This is chiefly formed of sedimentary rocks—those which have been formed by the settling of [Pg 10] sediment, in water.

While we are forced to these general conclusions in regard to the building of the world, and to its subsequent distortion by the series of upheavals that have occurred from time to time, and to the successive "ages" of the layers of rock foundation of its crust, there are many mysteries that remain unsolved and many questions will present themselves to the mind of the reader. One of these questions is, Where was the water and where was the earthy matter before its precipitation? Matter, including water, can exist in the gaseous form, and we only need to assume that there was a core of intense heat, to understand how all the material that we find on the earth and in the earth could have been held in suspension in the gaseous state until the cooling process had reached a stage where the various combinations and recombinations could take place in the great laboratory of nature. If we study the constitution of the sun (and with the modern appliances we are able to do so), we find that it is made up of some and perhaps all of the same materials that are found here on earth. If there is no water existing, in the sun, as water, there are the gases present which would produce it if the conditions were right. And, for all we know, that flaming mass of burning gases may some time go through the same kind of cooling [Pg 11] and building up in solids that our earth has experienced.

We thus have what may be called an outline sketch of the process of World-building.

CHAPTER II. [Pg 12]

LIMESTONE.

A large part of the structure of the earth's crust is formed of a substance called limestone. Ordinary limestone is a compound of common lime and carbon dioxide, a gas that is found mixed with the air to a very small degree. Carbon dioxide will be better known by the older people as carbonic acid. It is a gas that is given off whenever wood and coal are burned, or any substance containing carbon. It is composed of one atom of carbon to two of oxygen. Every ton of coal that is burned sends off three and two-thirds tons of this gas. The increase in weight comes from the fact that every atom of carbon unites with two of oxygen, which it takes from the air, and the oxygen is heavier than the carbon.

In comparing the relative weights of atoms (the smallest combinable particle of a solid, liquid, or gas) we use the hydrogen atom as the unit of comparison and call it "one," because it is the lightest of all atoms. The carbon atom is twelve times heavier than the hydrogen atom, and the [Pg 13] oxygen atom is sixteen times heavier. Hence it will be seen readily how a ton of coal will form two and two-thirds times its weight of carbonic dioxide. Lime, having a strong affinity or attraction for this gas, has absorbed it from the air and water, forming what is known as carbonate of lime—which is the ordinary limestone. Chalk and the various marbles are also carbonates of lime. Limestone strata in the crust of the earth are found in all the periods of the earth's formation. All forms of sea shells that were once the homes of animal life are constructed of this compound; and in the later formations of limestone, in the Secondary and Tertiary periods, we find this rock to be made up almost entirely of marine shells, some of them microscopic in size. The earlier or older formations of limestone that are found deeper down in the earth's crust are less mingled with these marine shells. This comes from the fact that the first deposition of limestone strata occurred before the later forms of sea life had developed. Whatever signs of life are found in these lower stratifications are of the very lowest order. It is not to be understood that animal life is a necessary factor in the formation of limestone, but it has been an incidental feature which no doubt has been the chief means of gathering up from the water this compound and precipitating [Pg 14] it into the great limestone strata that are everywhere found.

Carbonate of lime is found in solution in nearly, if not quite, all of the mineral waters, and is also found in the water of the ocean. In earlier times it must have been held in solution in much greater quantities than at present. The myriads of sea animals that existed, and that still exist, gathered from the water this substance, which formed their shells, and served as a house in which they lived. New germs were continually forming new shells, while the older ones ceased to live as animals, and their houses in which they lived were precipitated to the bottom of the ocean, where they were bound together as limestone rock. These sea animals no doubt caused a much more rapid formation of limestone than would or could have been the case without their existence.

One can thus readily see what an important factor animal life has been in the process of world-building. This process is still going on, but probably not to the same extent as in former ages, because it is not likely that there is so much carbonate of lime held in solution as there was before these great limestone beds were formed. Limestone, however, is easily disintegrated by the action of water. We find the spring water impregnated with it as well as that of the small [Pg 15] streams and rivers. Pure water is a powerful solvent. When the rains fall upon the earth the water percolates through it and through the limestone strata, which gradually wears away the limestone and carries it back to the ocean, so that the process of tearing down and building up is continually going on. The great caves that are found everywhere in the limestone regions were formed by the action of water. The great Mammoth Cave of Kentucky, which is said to have 200 miles of underground passages, has been entirely worn out by the action of running water.

Some years ago the writer visited this cave and had an opportunity to study the wonderful eroding or gnawing-out effect of water on limestone. At some period earlier in the history of the earth there was evidently an underground river or large stream of water that found its way through the crevices of the rocks, and gradually wore out a great bed for itself, which was fed by lateral streams pouring into the main branch, each one of which lateral branches cut its own channel. A plan view of the Mammoth Cave presents a picture not unlike that of a great river with numerous branches emptying into it, all of them showing the windings such as we see in a river and its feeders upon the surface of the earth. There are three sets of these channels, one above the other, and we do not find the water till we get to the bottom of the third underground [Pg 16] story, so to speak. There is one place in this system of underground channels where the dripping from the roof of the upper channels has cut a great well hole many feet in diameter perpendicularly down through the whole system to a great depth. The sides of this great well hole are fluted into grooves caused by the constant downflow of the water. Although the amount of water flowing down through this well hole is very small, it is continually at work. Like interest on money, it never rests, each minute that passes has eaten away some of the great rock.

In other portions of the cave the dripping of the water is so gradual that the carbonate of lime hardens and forms what are called stalactites, that hang like icicles from the roof of the cave. Sometimes the water runs down so slowly upon these stalactites that it evaporates as fast as it appears, leaving behind its little load of carbonate of lime. If, however, there is a drip, there are formations built also from the lime in the dropping water on the floor of the cave, and these are called stalagmites. In time the stalactites and the stalagmites will meet, forming a great column reaching from floor to ceiling. Some of these formations, when they are free from foreign substances, are very beautiful. They are also very hard, giving off a metallic musical tone when [Pg 17] struck by any hard substance.

We have already stated that limestone is a compound of ordinary lime and carbon dioxide, forming a carbonate of lime. This statement does not give a complete analysis of all the elements entering into limestone. In the first place lime itself is a compound formed of two elementary substances, calcium and oxygen. The lime molecule is composed of one atom of calcium and one of oxygen. Neither calcium nor lime is found pure in nature. Inasmuch as carbon dioxide is composed of one atom of carbon and two of oxygen, and lime is composed of one atom of calcium and one of oxygen, when we have the two combined the molecule of carbonate of lime, or, as it is technically called, calcic carbonate, is composed of one atom of calcium, one of carbon and three of oxygen, (lime plus carbon dioxide).

As before stated, lime is not found un-combined with other substances in nature. And as it is of great economic importance, it will be profitable to know how it is formed. Lime is produced from ordinary limestone by burning it in kilns where it is subjected to a heat of a certain temperature for a number of hours. The heat drives off the carbon dioxide, which, as we have seen, has taken away from each molecule of the compound all of the carbon and two atoms of the oxygen, while [Pg 18] all of the calcium is retained with one atom of oxygen, leaving ordinary lime. Lime, then, is simply oxide of calcium.

As all know, it is used almost exclusively for making mortar for building purposes. In order to do this we have to put it through the process of "slacking," by pouring water upon it, and here another chemical change takes place. The water unites with the lime, when immediately the heat that was expended in throwing off the carbon dioxide and was stored in the lime as energy is now given up again in the form of heat. When a considerable bulk of lime is slacked very rapidly the heat that is given off is so great that it will produce combustion. Here is a beautiful illustration of what has been erroneously called "latent heat." It is "heat stored as potential energy," that is released by the combination of lime with water. Slackened lime, then, is called calcic hydrate.

Very little of the limestone that we find is absolutely pure. It is considered good when it does not contain over five or six per cent. of foreign substance. When more than this is present the lime is considered poor, and when it reaches fifteen per cent. or more of impurities it assumes the property of hardening under water and is called cement.

Carbonate of lime is found in several other forms; for instance, the various kinds of marble and [Pg 19] chalk are carbonates of lime. The composition of marble and chalk is exactly the same as that of limestone. The difference is chiefly one of molecular rather than chemical structure. Marble is what chemists would call an allotropic or changed form of limestone; and, as before stated, the difference seems to consist in the fact that the marble assumes a crystalline arrangement of its atoms and will therefore take a high polish, which is not true of ordinary limestone. Marble varies greatly in coloring and texture, all of which differences are explainable under the one head of molecular arrangement. Nearly pure carbon exists in three distinct forms—the diamond, graphite, and charcoal. As is the case with marble, these differences in the different forms of carbon are not chemical, but molecular differences. The substances are the same, but their infinitesimal particles are differently arranged.

Carbonate of lime—as it exists in its various forms, as limestone, from which lime and cement are made, and marble, which is such an important element in the arts—is a substance of great importance to man. We have already noted some of the processes that nature uses in gathering up these substances from the ocean by the employment of various forms of animal life. Here is [Pg 20] another. Whoever has visited the Bermudas has seen an island wholly formed of what is called coral rock. Coral is a structure produced by a peculiar form of sea animal that gathers up the calcareous or lime-like matter floating in the sea water, and builds a house of it in which to live during the little lifetime that is allotted to him. When he dies his children do not occupy the old home, but build a new one, which is a superstructure planted upon the old one as a foundation. This process of growth sometimes takes the form of a tree or plant, and coral trees grow upon trees and plants upon plants, until a structure is erected having its foundation upon the bottom of the ocean, that finally reaches up until it rises above the surface of the water; and here—after through years the water has brought sea-weed and drift to decay and form soil, and the birds have brought seeds and fertilization, and vegetable life is prospering—another animal called man builds his home upon it. The material that the coral is formed of is substantially the same as that we find in the minute shells of the limestone rocks.

The great chalk cliffs that are found on the coasts of the English channel are the work of a sea animal microscopic in size. At one time it was a question among scientists how these chalk cliffs were formed, but when the microscope was invented this mystery, as well as many others, was [Pg 21] solved. The chemical components of chalk are precisely the same as those of limestone. The microscope shows that chalk is almost wholly a product of very small organized shells. The animals who are the architects of the chalk cliffs are called "foraminifera"—bearing shells perforated with little holes. The chief difference between chalk and limestone seems to be in the size of the shells of which they are respectively made up and in the manner of the bonding of these shells together. The shells in a lump of chalk are held much more loosely than those in a lump of limestone. These intrepid workers are still actively changing the structure of the bottoms of seas and oceans, and forming new islands, which in turn become the substructure that supports new life, animal and vegetable. And when we consider the great part performed by these microscopic architects and builders it is not a misnomer to speak of the building of a world.

CHAPTER III. [Pg 22]

COAL.

Some time, long ago, some man made the discovery that what we now call coal would burn and produce light and warmth. Who he was or how long ago he lived we do not know, but as all earthly things have a beginning, we know that such a man did live and that the discovery that coal would burn was made. Coal, in the sense that we use the word here, is not mentioned in the Scriptures. According to some authorities, coal was used in England as early as the ninth century. It is recorded that in 1259 King Henry III. granted a privilege to certain parties to mine coal at Newcastle. It is further stated that seven years after this time coal became an article of export. In 1306 coal was so generally used in London that a petition was sent to parliament to have the use of it suppressed on the ground that it was a nuisance. Coal was used in Belgium, however, about 1200. There is a tradition that a blacksmith first used it in Liège as fuel. It was [Pg 23] first used for manufacturing purposes about 1713.

Coal is found laid down in great veins, varying in thickness, in various parts of the world in the upper strata of the Paleozoic period. The age in which it was formed is called by geologists the Carboniferous (coal-bearing) age.

Before going on to account for the deposits of coal, let us stop a moment and consider what it is. Chemists tell us that coal is chiefly constructed of carbon, compounded with oxygen, hydrogen, and nitrogen. There are many varieties, but all may be classified under two general headings—bituminous and anthracite. Bituminous coal contains a large amount of a tarry substance, a kind of mineral pitch or bitumen, which burns with a brilliant flame and a black sooty smoke, exceedingly rich in carbon. Anthracite coal is hard and stone-like in its texture, burning with scarcely any flame and no smoke. It produces a fire of intense heat when it is once ignited. There is another form of coal called cannel coal, which is a corruption of "candle coal," so called because a piece of this kind of coal when ignited will burn like a match or pine knot and give light like a candle. This is the richest of all the coal deposits in gases that are set free by heat, and for this reason is extensively used in the manufacture of what is commonly called coal gas. England [Pg 24] produces a large amount of cannel coal, as well as another variety of bituminous coal, which latter, however, does not burn with such a black smoke as the coal found in the Ohio valley and the Western States of America. East of the Alleghany Mountains there is a region of anthracite coal that is very extensively worked and finds great favor in all parts of the country as fuel for domestic heating, especially on account of its great cleanliness.

All of the coal beds have a common origin, and the difference in the quality of coal found in different parts of the country is due to many circumstances, some of which have never been explained. There is indisputable proof, however, that all coal beds are of vegetable origin. Geologists tell us that these coal beds were formed during an age before the earth had cooled down to the temperature that it has at the present time—an age when vegetation was forced by the internal heat of the earth instead of having to receive all its warmth from the sun's rays as we do now. Some of our readers are familiar with what is commonly termed a hotbed. A hotbed is made by putting soil on top of substances that will ferment and create heat underneath the soil. This heat from beneath will force vegetation and cause a much larger growth than there will be if [Pg 25] left to the sun's rays alone. During the carboniferous age the earth was a great hotbed.

The fossils of trees and plants, as well as reptiles, that we find in the great coal measures of the world, show that they were of large tropical growth, and this is shown not only in the temperate zone, but in the zone farther north. For ages and ages this rank growth of vegetation grew up and fell down until a great layer of vegetable matter was formed, which at a later time was covered over by other stratifications of earth material, so that these great layers of vegetable formation were hermetically sealed and pressed down by an enormous weight that increased as time went on. The formation of coal may be studied even at this day (for it is now going on) by visiting and examining the great peat beds that are found in various parts of the world. It is well known that peat is used as a fuel by many people, especially the peasantry of the old countries. If peat is pressed to a sufficient degree of hardness it burns in a manner not unlike some forms of coal. Peat is a vegetable formation and has been formed by the rank growth of various kinds of vegetation in swampy places. Of course, it lacks the purity of the coal that was formed during the carboniferous age, because of the much slower growth of vegetation now than during that time, [Pg 26] and the opportunity that peat bogs offer for an intermixture of earthy with the vegetable matter. The fact that we find the imprint of trees and ferns and other vegetable growth of tropical varieties, as well as the fossils of reptiles, imbedded in the coal measures, proves that at one time this stratum was at the land surface of the earth. We also find that all of the formations of the Secondary and Tertiary periods are on top of the coal—and this shows that after the age of rank vegetable growth there was a sinking of the earth in many places far down into the ocean—so that vast layers of rock formed on top of these beds of vegetable matter. In England great chalk beds crop out in cliffs on the southern coast, and, as we have seen, these chalk rocks are largely made up of the shells of marine animals. London stands on a chalk bed, from six hundred to eight hundred feet thick. Indeed, England has been poetically called Albion, White-land, from this appearance of her coast.

All of the great chalk beds were formed ages after the coal beds, as the latter are found in the upper strata of the Paleozoic period.

A study of these strata will show that there are many layers of coal strata varying in thickness and separated by layers of shale and sandstone. How the shale and sandstone layers are formed [Pg 27] will be the subject of a future chapter.

From the position that the coal measures occupy, being entirely under the Secondary and Tertiary formations, it will be observed that they are very old. If we should examine a piece of ordinary bituminous coal we should find that there are lines of cleavage in it parallel to each other, and that it is an easy matter to separate the lump on these lines. If we examine the outcrop of a coal bed we will find that these lines of cleavage are horizontal. This indicates that the great bulk of vegetable matter of which the coal formation is made up has been subjected to tremendous pressure during a long period of time. If we further examine the structure of a body of coal we find the impressions of limbs and branches as well as the leaves of trees and various kinds of plants. We shall further find that these impressions lie in a plant in the same direction as the line of cleavage. This is a point to be remembered, as it helps to explain the nature and structure of other formations than those of coal. Not only are leaves and branches of vegetable matter found, but fossils of reptiles, such as live on the land. Sometimes there is found the fossil of a great tree trunk standing in an erect position, with its roots running down into the rock below the coal bed, while the trunk extends upward entirely through the coal and high up into [Pg 28] the other strata. All of these facts lead us to the firm conclusion that when the trees were grown that formed these beds they were above the surface of the ocean. This, taken in connection with the fact that the vegetable fossils that are found indicate a tropical growth of great size, drives us to the conclusion that the climate at the time these coal measures were formed was much warmer than it is now.

As already remarked, this extra warmth came from the earth itself before it had cooled down to its present temperature, rather than from the heat of the sun. There is nothing inconsistent in the thought that the sun may have been warmer in a former age than now. We may conceive that the earliest coal formations took place when the land stood above the surface of the water, and that the conditions were favorable for a rapid and luxuriant growth of vegetation; after this had gone on for a very long period of time, by some convulsion of nature the land surface was submerged under the ocean, when other mineral substances were deposited on top of this layer of vegetable growth, which hardened into a rock formation. At a later period the earth was again elevated above the surface of the water and the same process of growth and decay was repeated. These oscillations of the earth up and down occurred at enormously long intervals, until all of the [Pg 29] various coal strata with their intermediate formations were completed. After this we must suppose that the whole was submerged to a great depth and for a very long period of time, because of the great number and various kinds of rock formations laid down by water that lie on top of the coal measures. This tremendous weight, as it was gradually builded up, subjected these vegetable strata to an inconceivable pressure. In some places this pressure was much greater than in others, which undoubtedly is one of the reasons why we find such differences in the structure and quality of coal. There were no doubt many other reasons for differences, one of them being the character of the vegetable growth out of which they were formed. Again, in some parts of the world these coal strata may have been subjected to a considerable degree of heat, which would change the structure of the formation, and in some cases drive off the volatile gases. One can easily imagine that heat was thus a factor in the formation of what is known as anthracite coal, so much less gaseous than the bituminous kinds. The anthracite beds seem to be denser and of a more homogeneous character. The lines of cleavage are not as prominent, but there are the same evidences of vegetable origin that we find in the bituminous formations. [Pg 30]

It will be seen from what has gone before that coal was first wood. But wood is a product of sunshine. Thus the sun was the architect and builder of the trees and plants that were finally hermetically sealed under the great earth strata. The sun gathered up the material and set the forces in play which made the chemical combinations of the various elements in nature that enter into vegetable growth.

After the lapse of untold ages of time these great beds of stored-up sun-energy were discovered by man and their contents are dragged out to the earth's surface, to warm our houses, to drive the machinery of our factories, to send the locomotives flying across the continents and the steamships over the oceans. So important has this article become that if any one nation could control the output it would be able to paralyze all the navies and the manufacturing of the world.

If the coal of the world should become exhausted we should be confronted with a great problem. Fortunately for us, this is a problem that will have to be solved by the people of some future age, as the growth of wood will scarcely keep pace with the consumption of fuel. By that time the genius of man will have devised an economical means of storing the energy of the sunbeams directly for purposes of heat, light, and power.

[Pg 31]

CHAPTER IV.

SLATE AND SHALE.

Slate is one of the great commercial products of the world. As far back as the year 1877 the output of slate was not less than 1,000,000 tons per annum. The chief use to which slate is put is for covering buildings, and for this purpose it is better than any other known material. It is also used in the construction of billiard tables and for writing-slates; these latter uses are very insignificant as compared to its use in architecture. Slate, like building-stone and limestone, is quarried from the earth's crust and is found in the strata close above the Metamorphic rocks, near the beginning of what is called the Primary, or Paleozoic period. As compared with the coal formations it is very, very old.

There are different substances called slate that are not slate in the scientific use of that word. In general all stone formations are called slates that split up into thin layers. But the true slate is a special material which is formed by special processes of nature. The difference between slate and [Pg 32] shale, for instance, is not one of ingredients, but of the process by which the ingredients are put together. All of the sedimentary rocks are formed by a deposit of sediment from the water on the bottom of the ocean. At one period the floods have brought down a certain kind of material in greater profusion than at others, and this is deposited in thin layers, and as it hardens there will be seams in it and the stratifications will be differently colored, the color depending upon the deposit at any particular time.

A bed of shale, like a bed of coal, has lines of cleavage in it, and if it is examined under a microscope it will be found that the sedimentary particles, like the twigs and leaves in the coal veins, lie with their longest dimensions in line with the plane of cleavage. Shale in color looks like slate, and an analysis of the material of which it is formed shows that shale and slate are both made from the same. There is, however, a structural difference between the two which is very peculiar and very interesting. The slate is ordinarily a denser material and the lines of cleavage are often at right angles with those that we find in ordinary shale.

A slab of shale will be of a uniform color on any one line of cleavage. The color may change at the next line, and generally does, to a slight extent. It is easy to see, then, if we could change the [Pg 33] lines of cleavage in the shale, so as to run at right angles with their present lines, the face of a slab would show bands of different colors or shadings, such as we often see in slate. If you take a piece of clay that has been thoroughly mixed, and subject it to a very great pressure, and then examine the piece that has been submitted to pressure under a microscope and compare it with a piece of the clay after it has been thoroughly mixed, but has not been submitted to pressure, you will find that the two are very different in structure. The pressed clay will show that the particles of which it is made up have all turned, so that their longest dimensions are in a line at right angles with the direction of pressure. Here is an interesting fact that we must remember. And it is in this that we find the reason for the structural difference between shale and slate. The lines of cleavage in shale are not formed necessarily by pressure, but because in the disposition of the material of which it was formed the particles naturally laid themselves down so that their longest dimensions were on a horizontal line.

Ages after, when other rock and other formations had been laid down on top of the bed of deposited mud, the upheavals of the earth have so changed the lines of pressure upon this material and the pressure is so great that a rearrangement of the particles of which the slate is [Pg 34] made up has taken place, so that their longest dimensions now are in a direction that crosses the stratifications as originally laid down.

The effect of this is twofold. First, the material is compressed into a denser, closer form, and then, the lines of cleavage are changed, or to express it in more common language, the grain has been changed. So that when it splits up it runs crosswise of the original layers as the water deposited them, and this produces the different shadings so often seen in different slate. Shale splits in line with its layers; slate splits across that line.

Let us go back a moment to our experiment with the lump of clay. If we examined the mixture before submitted to pressure we should find that the oblong particles of which it was made up would stand in all directions, hit or miss, and if we should dry this lump of clay it would have no special lines of cleavage. But the moment we have submitted it to a certain amount of pressure we find that lines of cleavage have been established, and that the particles have been rearranged so that their longest dimensions are all in one direction, which coincides with the cleavage lines. If we should now take this same piece of clay and subject it to a pressure at right angles to that [Pg 35] of the first experiment we should find that the lines of cleavage had also changed and that the particles had all been rearranged. Apply the principle to the formation of slate, and we can understand how it happens that what we call the grain runs crosswise of the deposits that were made at different times. It is not a chemical, but purely a mechanical difference. Or, to express it differently—the difference is a structural one produced by mechanical causes.

The origin of cleavage in slate has been the subject of much speculation and investigation, but like many other problems it was solved through the invention and application of the microscope. Thin layers of slate have been made, the same as with limestone and chalk, so thin that the light would readily pass through it and that an examination of the particles could be readily made, showing their arrangement under varied conditions. Science is indebted to the microscope for the solution of very many problems that for ages before had puzzled philosophers.

CHAPTER V.

SALT.

It may seem curious to the reader that we should care to discuss a subject seemingly so simple as common salt. But it is a very usual thing for us to live and move in the presence of things that are very common to our everyday experience, and yet know scarcely anything about them, beyond the fact that they in some way serve our purpose.

Salt is one of the commonest articles used in the preparation of our food. It has been questioned by some people whether salt was a real necessity as an animal food, or whether the taste for it is merely an acquired one. All peoples in all ages seem to have used salt, and reference to it is made in the earliest histories. Travelers tell us that savage tribes, wherever they exist, are as much addicted to the use of salt as civilized people. One of the early African travelers, Mungo Park, tells us that the children of central Africa will suck a piece of rock salt with the same avidity and seeming satisfaction as the ordinary civilized child will a lump of sugar. [Pg 37]

All animals seem to require salt, and it is claimed by those who have tried the experiment that after one has refrained from the use of salt for a certain length of time the craving for it becomes exceedingly painful. It is most likely that the taste for salt is a natural craving. In any event, whether it is a natural or an artificial taste, it has become an article of the greatest importance in the preparation of food, as well as on account of its use in the arts. Salt is a compound of chlorine and sodium. In chemical language it is called sodium chloride. The symbol is NaCl, which means that a molecule of salt is composed of one atom of sodium and one of chlorine. Chlorine is an exceedingly poisonous gas.

Formerly the chemist when he wished to obtain sodium extracted it from common salt and discharged the chlorine gas into the air. It was found that in establishments where the manufacture of sodium was conducted on a large scale the destructive properties of the chlorine discharged into the air was such that all vegetation was killed for some distance around the manufactory. This came to be such a nuisance that the manufacturers were either compelled to stop business or in some way take care of the chlorine. This is done at the present day by uniting [Pg 38] the chlorine gas with common lime, forming a chloride of lime, which is used for bleaching and purifying purposes.

Salt is found in great quantities as a natural product under the name of rock salt. It is found in some parts of the world in great veins over 100 feet in thickness. In some cases the rock salt is mined, when it has to be purified for commercial purposes. The common mode of obtaining salt, however, is by pumping the solution from these great beds where it is mingled with water—salt water; the water is then evaporated, and when it reaches a certain stage of evaporation the salt crystallizes and falls to the bottom.

Different substances crystallize in different forms. The crystallization of water when it freezes, as we shall see hereafter, arranges its molecules in such a form as to make a lump of ice of given dimensions lighter than the same dimensions of water would be. Salt in crystallizing does not follow the same law; the salt crystal is in the shape of a cube and is denser in its crystalline form than in solution, hence it is heavier and falls to the bottom.

It is said that there is a deposit of rock salt in Galicia, Austria, covering an area of 10,000 square miles. There are also very large deposits in England, the mining of which has become a great industry. There are also great beds of salt in various parts of the United States, notably near [Pg 39] Syracuse, N. Y., where large salt deposits were exposed in an old river bed formed in preglacial times. The common mode of preparing salt for domestic purposes is by the process of evaporation from brine that has been pumped from salt wells. The quality of the salt is determined largely by the temperature at the time of evaporating the water from it. Ordinary coarse salt, such as is used for preserving meat or fish, is made at a temperature of about 110 degrees; what is known as common salt is made at a temperature of about 175 degrees; while common fine or table salt is made at a temperature of 220 degrees. Thus it will be seen that the process of granulation with reference to its fineness is determined by the rapidity of evaporation. Salt is one of the principal agents in preserving all kinds of meats against putrefaction. It will also preserve wood against dry rot. Vessel builders make use of this fact to preserve the timbers used in the construction of the vessels.

Salt at the present day is very cheap, but at the beginning of the present century it was worth from $60 to $70 per ton. The methods of decomposing salt to obtain its constituents, which are used in various other compounds, are very simple to-day as compared with the processes that prevailed in the days before the advent of electricity in large volume, such as is produced by the [Pg 40] power of Niagara Falls. It is curious to note that a substance so useful and so harmless as common salt should be made out of two such refractory and dangerous elements as chlorine and sodium. Both of these elements, standing by themselves, seem to be out of harmony with nature, but when combined there are few substances that serve a better purpose.

These great salt beds that are found to exist in England and America and other parts of the world were undoubtedly deposited from the water of the ocean at some stage in the formation of the earth's crust. It is well known that sea water is exceedingly saline; 300 gallons of sea water will produce a bushel of salt. Undoubtedly beds of salt are also formed by inland lakes, such as the Great Salt Lake in Utah. Only about 2.7 per cent. of ocean water is salt, while the water of the

Great Salt Lake of Utah contains about 17 per cent. When there is so much salt in water that it is called a saturated solution, salt crystals will form and drop to the bottom, which process will in time build up under a large body of salt water a great bed of rock salt.

The water in all rivers and springs contains salt to a certain degree, and where it runs into a basin like that of a lake with no outlet, through the process of evaporation pure water is being [Pg 41] constantly carried off, leaving the salt behind. It is easy to see that if this process is kept up long enough the water will become in time a saturated solution, when crystallization sets in and precipitation follows, accounting for the deposits of rock salt.

AIR.

[Pg 42]

CHAPTER VI.

THE ATMOSPHERE.

Meteorology is a science that at one time included astronomy, but now it is restricted to the weather, seasons, and all phenomena that are manifested in the atmosphere in its relation to heat, electricity, and moisture, as well as the laws that govern the ever-varying conditions of the circumambient air of our globe. The air is made up chiefly of oxygen and nitrogen, in the proportions of about twenty-one parts of oxygen and seventy-nine parts nitrogen by volume, and by weight about twenty-three parts oxygen and seventy-seven of nitrogen. These gases exist in the air as free gases and not chemically combined. The air is simply a mixture of these two gases.

There is a difference between a mixture and a compound. In a mixture there is no chemical change in the molecules of the substances mixed. In a compound there has been a rearrangement [Pg 43] of the atoms, new molecules are formed, and a new substance is the result.

About 99-1/2 per cent. of air is oxygen and nitrogen and one-half per cent. is chiefly carbon dioxide. Carbon dioxide is a product of combustion, decay, and animal exhalation. It is poison to the animal, but food for the vegetable. However, the proportion in the air is so small that its baneful influence upon animal life is reduced to a minimum. The nitrogen is an inert, odorless gas, and its use in the air seems to be to dilute it, so that man and animals can breathe it. If all the nitrogen were extracted from the air and only the oxygen left to breathe, all animal life would be stimulated to death in a short time. The presence of the nitrogen prevents too much oxygen from being taken into the system at once. I suppose men and animals might have been so organized that they could breathe pure oxygen without being hurt, but they were not, for some reason, made that way.

Air contains more or less moisture in the form of vapor; this subject, however, will be discussed more fully under the head of evaporation. The air at sea-level weighs fifteen pounds to the square inch, and if the whole envelope of air were homogeneous—the same in character—it would reach only about five miles high. But as it becomes gradually rarefied as we ascend, it probably extends in a very thin state to a height of eighty or ninety miles; at least, at that height we should find a [Pg 44] more perfect vacuum than can be produced by artificial means. The weight of all the air on the globe would be 11-2/3 trillion pounds if no deduction had to be made for space filled by mountains and land above sea-level. As it is, the whole bulk weighs something less than the above figures.

As we have said, the air envelopes the globe to a height at sea-level of eighty or ninety miles, gradually thinning out into the ether that fills all interstellar space. We live and move on the bottom of a great ocean of air. The birds fly in it just as the fish swim in the ocean of water. Both are transparent and both have weight. Water in the condensed state is heavier than the air and will seek the lowest places, but when vaporized, as in the process of evaporation, it is lighter than air and floats upward. In the vapor state it is transparent like steam. If you study a steam jet you will notice that for a short distance after it issues from the boiler it is transparent, but soon it condenses into cloud.

If we could see inside of a boiler in which steam had been generated, all the space not occupied with water would seem to be vacant, since steam before it is condensed is as transparent as the air. We will, however, speak of this subject more fully under the head of evaporation and cloud [Pg 45] formation. It is not enough that we have the air in which we live and move, with all of its properties, as we have described: something more is needed which is absolutely essential both to animal and vegetable life—and this essential is motion. If the air remained perfectly still with no lateral movement or upward and downward currents of any kind, we should have a perfectly constant condition of things subjected only to such gradual changes as the advancing and receding seasons would produce owing to the change in the angle of the sun's rays. No cloud would ever form, no rain would ever fall, and no wind would ever blow. It is of the highest importance not only that the wind shall blow, but that comparatively sudden changes of temperature take place in the atmosphere, in order that vegetation as well as animal life may exist upon the surface of the globe. The only place where animal life could exist would be in the great bodies of water, and it is even doubtful if water could remain habitable unless there were means provided for constant circulation—motion.

The mobility of the atmosphere is such that the least influence that changes its balance will put it in motion. While we can account in a general way for atmospheric movements, there are many problems relating to the details that are unsolved. We find that even the "weather man" makes [Pg 46] mistakes in his prognostications; so true is this that it is never safe to plan a picnic for to-morrow based upon the predictions of to-day. The chief difficulty in the way of solving the great problems relating to the sudden changes in the weather and temperature lies in the fact that two-thirds or more of the earth's surface is covered with water; thus making it impossible to establish stations for observation that would be evenly distributed all over the earth's surface. Enough is known, however, to make the study of meteorology a most wonderfully interesting subject.

We have already stated that air is composed of a mixture of oxygen and nitrogen chiefly, with a small amount of carbon dioxide. So far as the life and health of the animal is concerned we could get along without this latter substance, but it seems to be a necessity in the growth of vegetation. There are other things in the air which, while they are unnecessary for breathing purposes, it will be well for us to understand, as some of them are things to be avoided rather than inhaled.

As before mentioned, air contains moisture, which is a very variable quantity. In a cold day in winter it is not more than one-thousandth part, while in a warm day in summer it may equal one-fortieth of the quantity of air in a given space. There is also a small amount of ammonia, perhaps [Pg 47] not over one-sixty-millionth. Oxygen also exists in the air in very small quantities in another form called ozone. One way to produce ozone is by passing an electric spark through air. Anyone who has operated a Holtz machine has noticed a peculiar smell attending the disruptive discharges, which is the odor of ozone. It is what chemists call an allotropic form of oxygen, just as the diamond, graphite, and charcoal are all different forms of carbon, and yet the chemical differences are scarcely traceable. It is more stimulating to breathe than oxygen and is probably produced by lightning discharges.

As has been before stated, the oxygen of the air is consumed by all processes of combustion, and in this we include the breathing of men and animals and the decay of vegetable matter, as well as the more active combustion arising from fires. A grown person consumes something over 400 gallons of oxygen per day, and it is estimated that all the fires on the earth consume in a century as much oxygen as is contained in the air over an area of seventy miles square. All of these processes are throwing into the air carbon dioxide (carbonic acid), which, however, is offset by the power of vegetation to absorb it, where the carbon is retained and forms a part of the woody fiber and pure oxygen is given back into the air. By this process the normal conditions of the air [Pg 48] are maintained.

One decimeter (nearly 4 inches) square of green leaves will decompose in one hour seven cubic centimeters of carbon dioxide, if the sun is shining on them; in the shade the same area will absorb about three in the same time.

There is another substance in the form of vegetable germs in the air called bacteria. At one time these were supposed to be low forms of animal life, but it is now determined that they are the lowest forms of vegetable germs. Bacteria is the general or generic name for a large class of germs, many of them disease germs. By analysis of the air in different locations and in different parts of the country it has been determined that on the ocean and on the mountain tops these germs average only one to each cubic yard of air. In the streets of the average city there are 3000 of them to the cubic yard, while in other places where there is sickness, as in a hospital ward, there may be as many as 80,000 to the cubic yard. These facts go to prove what has long been well known, that the air of a city furnishes many more fruitful sources for disease than that of the country. Some forms of bacterial germs are not considered harmful, and they probably perform even a useful service in the economy of nature. Within certain limits, other things being equal, the higher one's dwelling is located above the common level the purer will be the air. This [Pg 49] rule, however, has its limits, as the oxygen of the air is heavier than the nitrogen, so that the air at very great altitudes has not the same proportion of oxygen to nitrogen that it has at a lower level. An analysis that was made some years ago of the air on the west shore of Lake Michigan, especially that section where the bluffs are high, shows that it compares favorably with that of any other portion of the United States.

In view of the foregoing, it is of the highest importance to the sanitary condition of any city, town, or village that it be not too compactly built. If more than a certain number of people occupy a given area, it is absolutely impossible to preserve perfect sanitary conditions. And there ought to be a State law, especially for all suburban towns, which are the homes and sleeping places for large numbers of business men who spend their days in the foul air of the city, stipulating that the houses shall be not less than a certain distance apart. Oxygen is the great purifier of the blood, and if one does not get enough of it he suffers even though he breathes no impurities. The power to resist the effects of bad air is much greater when one is awake and active than when asleep, and this is why it is more important to sleep in pure air than to be in it during our waking [Pg 50] hours. It is best, however, to be in good air all of the time. By pure air I do not mean pure oxygen, but the right mixture of the two gases that make air. Too much of a good thing is often worse than not enough. Pure food to eat, pure water to drink, and pure air to breathe would soon be the financial ruin of a large class of doctors.

CHAPTER VII.

AIR TEMPERATURE.

The most recent definition of heat is that it is a mode of motion; not movement of a mass of substance, but movement of its ultimate particles. It has been determined by experiment that the ability of any substance to absorb heat depends upon the number of atoms it contains, rather than its bulk or its weight.

It has also been stated that the atmosphere at sea-level weighs about fifteen pounds to the square inch, which means that a column of air one inch square extending from sea-level upward to the extreme limit of the atmosphere weighs fifteen pounds. The density of the air decreases as we ascend. Each successive layer, as we ascend, is more and more expanded, and consequently has a less and less number of air molecules in a given space. Therefore the capacity of the air for holding heat decreases as we go higher.

We deduce from these facts that the higher we go the colder it becomes; and this we find to be the case. Whoever has ascended a high mountain has had no difficulty in determining two things. One is that the air is very much colder than at sea-level, and the other that it is very much lighter in weight. We find it difficult, when we first reach the summit, to take enough of oxygen into our lungs to carry on the natural operations of the bodily functions. To overcome this difficulty, if we remain at this altitude for a considerable time, we shall find that our lungs have expanded, so as to make up in quantity what is lacking in quality.

If a man lives for a long time at an altitude of 10,000 feet he will find that his lungs are so expanded that he experiences some difficulty when he comes down to sea-level. And the reverse is true with one whose lungs are adapted to the conditions we find at sea-level, when he ascends to a higher altitude. There is a constant endeavor on the part of nature to adapt both animal and vegetable life to the surroundings. While no exact formula has been established as to the rate of decrement of temperature as we ascend, we may say that it decreases about one degree in every 300 or 400 feet of ascent. There is no exact way of arriving at this, as in ascending a mountain the temperature will be more or less affected by local conditions. If we go up in a balloon we have to depend upon the barometer as a means of measuring altitude, which, owing to the varying atmospheric conditions, is not a reliable mode of measurement. It is easily understood that a cubic foot of air at sea-level will contain a great many more atoms than a cubic foot of air will at the top of a high mountain; or, to state it in another way, a cubic foot of air at sea-level will occupy much more than a cubic foot of space 10,000 feet higher up. Suppose, then, that the amount of heat held in a cubic foot of air at sea-level remained the same, as related to the number of atoms. In its ascent we shall find that at a high altitude the same number of atoms that were held at sea-level in a cubic foot have been distributed over a so much larger space that the sensible heat is greatly diminished or diluted, so to speak. It was an old notion that heat would hide itself away in fluids under a name called by scientists latent heat. This theory has been exploded, however, by modern investigation.

If we place some substance that will inflame at a low temperature in the bottom of what is called a fire syringe (which is nothing but a cylinder bored out smoothly, with a piston head nicely fitted to it, so that it will be air-tight) and then suddenly condense the air in the syringe by shoving the plunger to the bottom, we can inflame the substance which has been placed in the bottom of the cylinder. In this operation the heat that was distributed through the whole body of air, that was contained in the cylinder before it was compressed, is now condensed into a small space. If we withdraw the plunger immediately, before the heat has been taken up by the walls of the syringe, we shall find the air of the same temperature as before the plunger was thrust down. This, however, does not take into account any heat that was generated by friction.

Let us further illustrate the phenomenon by another experiment. If we suddenly compress a cubic foot of air at ordinary pressure into a cubic inch of space, that cubic inch will be very hot because it contains all the heat that was distributed through the entire cubic foot before the compression took place. Now let it remain compressed until the heat has radiated from it, as it soon will, and the air becomes of the same temperature as the surrounding air. What ought to happen if then we should suddenly allow this cubic inch of air to expand to its normal pressure, when it will occupy a cubic foot of space?

Inasmuch as we allowed the heat to escape from it when in the condensed form, when it expands it will be very cold, because the heat of the cubic inch, now reduced to the normal temperature of the surrounding air, is distributed over a cubic foot of space.

This is precisely what takes place when heated air at the surface of the earth (which is condensed to a certain extent) rises to the higher regions of the atmosphere. There is a gradual expansion as it ascends, and consequently a gradual cooling, because a given amount of heat is being constantly distributed over a greater amount of space. At an altitude of forty-five miles it will have expanded about 25,000 times, which will bring the temperature down to between 200 and 300 degrees below zero.

When we get beyond the limits of the atmosphere we get into the region of absolute cold, because heat is atomic motion, and there can be no atomic motion where there are no atoms.

We have now traced the atmosphere up to the point where it shades off into the ether that is supposed to fill all interplanetary space. As Dryden says:

> There fields of light and liquid ether flow,
> Purg'd from the pond'rous dregs of earth below.

By interplanetary space we mean all space between the planets not occupied by sensible material. It is the same as interatomic space, or the space between atoms, except in degree, as the same substance that fills interplanetary space also fills interatomic space, so that all the atoms of matter float in it and are held together from flying off into space by the attraction of [Pg 56] cohesion. What this ether is, has been the subject of much speculation among philosophers, without, however, arriving at any definite conclusion, further than that it is a substance possessing almost infinite elasticity, and whose ultimate particles, if particles there be, are so small that no sensible substance can be made sufficiently dense to resist it or confine it. It is easy to see that a substance possessing such qualities cannot be weighed or in any way made appreciable to our senses. But from the fact that radiant energy can be transmitted through it, with vibrations amounting to billions per second, we know that it must be a substance with elastic qualities that approach the infinite. Assuming that the ether is a substance, the question arises how is it related to other forms of substance? This is a question more easily asked than answered. The longer one dwells upon the subject, however, the more one is impressed with the thought that after all the ether may be the one element out of which all other elements come.

Chemistry tells us that there are between sixty and seventy ultimate elements. This is true at least as a basis for chemical science. Chemical analysis has never been able to make gold anything but gold, or oxygen anything but oxygen, and so on through the whole catalogue of elements. It may be, however, that the play of forces under and beyond those that seem to be [Pg 57] active in all chemical processes and relations, are able to produce certain affections of the ether, the result of which in the one case is an atom of gold and in the other an atom of oxygen, etc., to the end of the list. In this case all of the so-called elements may have their origin in one fundamental element that we call the ether. I am aware that we are wading in deep water here, but sometimes we love to get into deep water just to try our swimming powers. The above is a suggestion of a theory called "the vortex theory," that is taking root in the minds of many philosophers to-day, and yet there is almost nothing of known facts to base such a theory upon, and nearly all we can say about it is that it seems plausible, when viewed through the eye of imagination.

We do know that substances, such as fluids or gases, assume very different qualities when put into different rates of motion. A straw has been known to penetrate the body of a tree endwise by the extreme velocity imparted to it when carried in the vortex of a tornado. Instances of the terrific solid power of substances that are mobile when at rest are often exhibited during the progress of a tornado, especially when confined in very narrow limits. Sometimes a tornado cloud will form a hanging cone, running down to a sharp point at the lower end, which lower end may [Pg 58] drag on the ground, or it may float a little distance above the ground, but more frequently it moves forward with a bounding motion, now touching the earth and now rising in the air. This cone is revolving at a terrific speed. The substance revolving is chiefly air, carrying other light substances that it has gathered up from the ground. If it comes in contact with a tree or building it cuts its way through as though it were a buzzsaw revolving at a high rate of speed. This is not simply the force of wind, but a kind of solidity given to the fluent air by its whirling motion.

I remember a case in Iowa, where one of these revolving cones passed through a barnyard, striking the corner of the barn, cutting it off as smoothly as though done with some sharp-edged tool, but it in no other way affected the rest of the building. One would suppose that the centrifugal force developed in this whirling motion would cause the cone to fly apart, and why it does not no one certainly knows. But we are obliged to accept the fact.

These cases are cited to show that motion gives rigidity to substances that in the quiescent state are mobile or easily moved, like the straw or the air. If we should assume that there are infinitesimal vortices or whirling rings in the ether, of such rapidity as to give it different degrees [Pg 59] of rigidity, we can get a glimmering idea of how an atom of matter may be formed from ether.

Referring to the rigidity which motion gives to ordinary matter, it is well known that when two vessels at sea collide the one having the higher speed is not so liable to injury as the one with the lower. The reader will perhaps remember a circumstance said to have occurred a few years ago on the Lake Shore Railroad, between Buffalo and Cleveland. The limited express was going west, and while rounding a curve the engineer suddenly came in sight of a wrecked freight train, a part of which was lying on the track where the express train had to pass. The engineer saw that he was too near the wreck to stop his train and that the only way to save his own train and the lives of his passengers would be to cut through the wreck. He pulled out the throttle and put on a full head of steam, and when the train struck the wreck it was going at such a high rate of speed that it cut through without seriously damaging the train and without harm to the passengers.

There are other heroes beside those who lead armies in battle.

[Pg 60]

CHAPTER VIII.

CLOUD-FORMATION—EVAPORATION.

Water exists in different forms without, however, undergoing any chemical change. It is when condensed into the fluid state that we call it "water," and then it is heavier than the atmospheric air and therefore seeks the low places upon the earth's surface, the lowest of which is the bed of the ocean. Wherever there is water or moisture on the face of the globe there is a process going on at the surface called evaporation. This process is much more rapid under the action of heat than when it is colder. In other words, as the heat increases evaporation increases within certain limits and bears some sort of a ratio to it. Evaporation is not confined to water, but as our subject has to deal with atmospheric phenomena we will speak of it only in its relation to aqueous moisture.

The heat that is imparted to the earth's surface by the rays of the sun is able to separate water into minute particles, which, when so separated, form what is called vapor, which is transparent, [Pg 61] as well as much lighter than the air at the surface of the earth. Being lighter than the air, it rises when disengaged and floats to the upper regions of the atmosphere. The atmosphere will contain a certain amount of these transparent globules of moisture in the spaces between its own molecules. If the air is warm the molecules will be farther apart and it will contain more moisture than when it is cold.

The process of evaporation is one of the most important in the catalogue of nature's dynamics. Without it there would be no verdure on the hills, no trees on the plains, no fields of waving grain, and no animal life upon the land surface of the globe. Evaporation is nature's method of irrigation, and the system is inaugurated on a grand scale, so that there are but few neglected spots upon the face of the earth which moisture, carried up from the great reservoirs of water, does not reach. The rate of evaporation, other things being equal, depends upon the extent of surface; therefore a smooth surface like that of the lake or ocean will not send up as much vapor from a given area in square miles as an equal area of land will do, when it is saturated with moisture, for the reason that there is a much larger evaporating surface on a square mile of land, owing to its inequalities, than upon an equal area of smooth water. Of course, if the earth is dry [Pg 62] there can be but little evaporation. One of the effects of evaporation is to withdraw heat, and so to produce cold in the substance from which the evaporation takes place.

If we put water into a vial and drop regularly upon it some fluid that evaporates readily it will extract the heat from the vial and the water in it to such an extent that in a short time the water will be frozen. In hot countries ice is manufactured on a large scale upon the principle that we have just described. Water is put into shallow basins, excavated in the earth, over which is placed some substance like straw that readily radiates heat, and on the straw are placed porous bricks, that are kept wet, thus furnishing a very large evaporating surface. In this way the process of evaporation is carried on very rapidly and the heat is extracted from the water to such an extent that it freezes, often forming ice in one night over an inch in thickness, and this in the hottest climates on the globe. Evaporation cannot go on in places where the air is already saturated with moisture. When the air is dry evaporation is very rapid, but as it becomes more and more filled with moisture the evaporation is checked to the same degree. This fact accounts for the difference of bodily comfort that we experience at different times in the year when the temperature is the same. Sometimes we are very uncomfortable although the temperature is not [Pg 63] above 75 degrees Fahrenheit, more so even than we are at other times when the temperature is ten or fifteen degrees higher. If the air is saturated with moisture, even though the temperature is not above 70 or 75 degrees, the perspiration is not readily evaporated from the surface of the body. If the air is dry the temperature may be much higher and we be much more comfortable, because evaporation goes on rapidly, which keeps the body not only dry, but cool. I remember passing through a desert in Arizona where there was scarcely a green thing in sight in any direction, and the temperature was said to be 140 degrees. I did not suffer as much as I often have done in the East with the thermometer at 80 or 90 degrees, and there was very little show of sensible perspiration; it was going on rapidly, however, but was being absorbed by the dry air. This goes to show that temperature is not the only factor to be considered when we are making an estimate of the good or bad qualities of a climate.

Evaporation is carried on much more rapidly when the wind blows than at other times, for the reason that the moisture is carried off laterally as fast as it is formed, all resistance to its escape into the upper air being removed. If the air is charged to saturation with moisture at a certain temperature, it will remain so, and evaporation stops so long as the temperature remains [Pg 64] unchanged. If its temperature rises the process of evaporation can start up, because the capacity of the air for holding moisture has been increased. But if a temperature is perceptibly lowered another phenomenon will manifest itself.

In the uncondensed state vaporized moisture is quite transparent, so that we are able to see through it as we do through a pane of glass. If, however, the body of air that is saturated with this invisible moisture becomes suddenly chilled, the moisture condenses into cloud or mist.

If we watch a passing railroad train we shall notice a mass of fleecy white mist floating away from the smokestack, assuming the billowy forms of some of the clouds in summer. This cloud is produced by the sudden condensation of steam, which was transparent before it came in contact with the cold, outside air, the effect being much more pronounced in cold than in warm weather. We may liken these floating globules of mist to the dust of the earth which floats in the air, and it has not been inaptly called water-dust. Anyone who has seen an atomizer used or has stood at the foot of a great waterfall, like Niagara, has seen the fluid so finely divided that it will float in the air, instead of falling to the ground. What takes place is that a number of these transparent atoms of moisture that are released in the process of evaporation coalesce into one small drop or [Pg 65] particle of water, and they will continue to float in the air as mist or cloud until a sufficient number have combined into one solid mass to render that mass heavier than the air, when it falls in the form of rain.

If we live in a region—and there are such on the face of the earth—where there is very little evaporation and consequently very little moisture in the air, there is rarely ever a cloud seen nor is there any rainfall, for the reason that there is no material existing out of which to form clouds, and the clouds precede the rain. Hence, all the artificial attempts to produce rain in these arid regions have been futile. If a body of warm air, when saturated with invisible moisture, is suddenly chilled by coming in contact with a cold wave, it is squeezed like a sponge, so to speak, and the invisible particles become visible because a number of them have coalesced as one particle; the particles gather in a large mass, and we have the phenomenon of cloud formation.

Clouds more generally form in the upper regions of the atmosphere because it is normally colder in the higher regions. In some cases clouds float very high in the air and in others very low. This is due to two causes:

If we should send up a balloon containing air rarefied to a certain extent it would continue to [Pg 66] ascend only until it reached a point where the outside air and that contained in the balloon are of the same density. If we should send up this same balloon on different days with the same rarefaction of internal air we should find that on some days it would float higher than others, because the density of the air is constantly fluctuating, as is indicated by the rise and fall of the barometer. Now let us consider the balloon as a globule of moisture of a definite weight, and this globule only one of an aggregation of globules sufficient to form a cloud. We can readily see from what has gone before that a cloud thus formed, having a definite density and weight, would float higher some days than others.

Assuming again that the density of the air remains the same from day to day, the clouds will still float high or low in the atmosphere from another cause. Let us go back to our illustration of the balloon. If we have a fixed condition of atmosphere, external to the balloon, and vary the conditions internally, which means varying its weight, the balloon will float higher or lower as the internal conditions are varied. Now apply this principle to the moisture globules of which a cloud is formed and we can understand why a cloud will float high or low from the two causes that we have described. Clouds are of different color and density, and this is due to the differences of the [Pg 67] make-up of the moisture globules of which the clouds are formed. If these globules are in an advanced stage of condensation the cloud is darker and more opaque. In earlier conditions of condensation the cloud will have a bright look, which shows that it reflects most of the light, whereas in the case of the dark cloud the light is largely absorbed.

There is a sort of notion prevailing that clouds come up from the horizon, and in many cases they do, but they may form directly over our heads. There always has to be a beginning, and that occurs wherever the conditions are most favorable for condensation of vapor. If the earth is wet and the sun is hot the evaporation may be very rapid as well as the ascent of the invisible moisture, which carries with it the air, which in turn expands the higher it rises, thus producing cold. This, taken with the normal cold that exists in the higher regions, may be sufficient to produce a sudden condensation of this ascending vapor, which is all that is necessary to form a cloud.

The inquiry may arise, Why is the moisture condensed, almost always, in the upper regions of the air, where it is rare? Because the more rare and therefore expanded it is, the more moisture it will hold. This, taken with the fact that cold currents are encountered high up, sufficiently answers the question.

It is interesting to know that the processes of nature are interdependent. It is not enough that we [Pg 68] have the evaporation of moisture that will ascend into the higher regions of the air and there be condensed into cloud and possibly rain, but we must have the means for distributing these conditions over a large area, and for this purpose we have the phenomenon of wind. Why the winds blow can be accounted for to a certain extent,—we might say to a large extent,—but there yet remain many unsolved problems relating to wind and weather. Of the phenomena of wind we will speak more fully in a future chapter.

CHAPTER IX. [Pg 69]

CLOUD FORMATION—CONTINUED.

As water in its condensed state is 815 times heavier than air, the question naturally comes to one why it does not immediately fall to the earth when it condenses. There are at least two and probably more stages of condensation. Investigators into the phenomenon of cloud formation claim to have ascertained that the first effect of condensation is to form little globes of moisture that are hollow, like a bubble, with very thin walls. Everyone has recognized the ease with which a soap bubble will float in the air, and yet it is simply a film of moisture. These little balloons, so to speak, are called spherules. It is undoubtedly the case that mingled with these little bubbles of moisture there are fine particles of solid water hanging on and carried along with them. Undoubtedly this is true; at least just before the final act of condensation takes place; and when the little hollow spherules collapse they are gathered together in drops of water larger or smaller according to the rapidity of condensation. There is probably another power at work to prevent [Pg 70] the too ready precipitation of moisture when condensed, and that is the wind. A cloud never stands still, although in some cases it may appear to do so. If we take a stone in our hand and allow it to drop without applying any force to it, it will fall directly to the ground. But if we give it an impetus in a horizontal direction it will travel some distance before striking the ground. If we could give the same impetus to a body as light as a globule of water-dust it would probably travel indefinitely without falling. Dust that would settle directly to the ground from an elevation in still air would travel thousands of miles without falling, before a wind having any considerable velocity.

Suppose the sun to be shining with intense heat upon a certain area of the earth's surface and the conditions to be right for very rapid evaporation of moisture. The air which is heated close to the ground, being expanded, will rise, together with the invisible particles of moisture, and there will be a column of moisture-laden air continually ascending until it reaches a point in the upper atmosphere where it is condensed into a cloud that takes on the billowy form which in summer time we call a thunder cloud, but which in the science of meteorology is called cumulus, or heap-cloud. If there were no air currents this billowy cloud would stand as the capping of an invisible [Pg 71] pillar of ascending vapor, but as it is never the case that air is not moving at some velocity in the upper regions, it floats away as rapidly as it is formed. This peculiar kind of cloud is formed in the mid-regions of the atmosphere, and it is a summer cloud as well as a land cloud. Of course, it may float off over the ocean and maintain its peculiar shape for a certain distance, but it is rare that such a cloud would ever be seen in mid-ocean or in midwinter. As the warm season advances in summer, and evaporation from the earth is less than the rainfall, there is less and less moisture in the air, when, of course, the conditions for cloud formation, especially inland, are not so favorable as in the early spring or summer. Frequently there comes a time when we have a long season of dry, settled weather. Probably during most of the days clouds will form and we think it is going to rain, but before night they have vanished, and the same thing is repeated the next day and the next, perhaps for weeks at a time.

The explanation is this: We have already said that so long as the air remains in a uniform condition as to temperature it will absorb moisture in a transparent state until it is filled to the measure of its capacity at a given temperature. If there were no change of temperature, it would not condense into cloud. Clouds may be absorbed into the atmosphere—or evaporated—and [Pg 72] become invisible; and this process is going on to a greater or less degree continually. If we watch the steam as it escapes from a steam boiler, the first effect is condensation into cloud, but as it floats away it gradually melts and is absorbed into the atmosphere as invisible vapor. This is especially true on a warm day; the same process takes place in the air that is going on at the level of a body of water or at the surface of moist earth.

As before stated, condensation always takes place when a body of moisture-laden air comes in contact with cold. When the steam escapes from a boiler, even on the hottest day, it is hotter than the surrounding air; the first effect is condensation, and then evaporation takes place the same as it would at the surface of the earth when the condensed particles of moisture are separated into the invisible atoms that accompany evaporation.

In settled, dry weather as the sun approaches the zenith, the earth becomes intensely heated, and there is an ascending column of air partly laden with moisture; but not to the same extent as earlier in the season. Condensation takes place and clouds are formed, but as there is not sufficient moisture to carry them to the point of a further condensation,—which would result in precipitation,—as the sun lowers in the west and the heated air becomes more evenly distributed [Pg 73] this condensed vapor is reabsorbed into the air as invisible moisture by a process allied to that of evaporation. This condition of things would extend to a much longer period than it does in our latitude if it were not for the gradual changing of the seasons, which finally destroys the balance in the dynamics of cloud-land and allows the cold—that has been held back for the time—in the great northern zone to get the upper hand. Then we have what is termed in common parlance a change in the weather, or, more properly in this case, a change in the season.

We have already spoken of the cloud called cumulus (which means heap) and of its performance during the dry season of summer. There is another form of cloud that is seen at this season of the year called cirrus (a curl). It takes the form of a curl at its ends. This cloud usually has a threaded shape and sometimes takes the form of a feather, and frequently forms are seen that remind you of frost pictures on a window pane. These clouds float very high in the atmosphere, away above the tops of the highest mountains, from six to eight miles above the level of the sea. They are formed only at a season of the year when the atmospheric conditions are most uniform. At certain times of the day and night the moisture will rise to this height before it condenses and when it [Pg 74] does condense it immediately freezes, which makes it take on these peculiar forms that would no doubt conform very closely to the frost pictures on the window pane if it were not for the disturbing influences of air currents at this altitude. The fact that they are ice or frost clouds instead of water clouds gives them that peculiar whiteness and brightness of appearance. If ordinary clouds are water-dust these high clouds may be called ice-dust. Sometimes we see them lying in bands or threads running across the sky in the direction that the wind blows. Their form is undoubtedly a resultant of the struggle between the air currents and the tendency of crystallized water to arrange itself in certain definite lines or forms. This cloud may be said to be one extreme, having its home in the highest regions of cloud-land, while the cumulus, or thunder cloud, is the other extreme and occupies the lower or mid regions of the air.

There is a still lower cloud of course, as ordinary fog is nothing more than cloud, which under certain conditions lies on the surface of the ocean or dry land. Fogs prevail when the barometer is low. As soon as it rises from the source of evaporation the moisture condenses almost to the point of precipitation. There is not enough buoyancy in its globules when the air is light, as it is [Pg 75] when we have a low barometer, to cause the fog to float into the higher regions of the atmosphere.

The high clouds, which are called cirrus, under certain conditions drop down to where they begin to melt into ordinary moisture globules, and while this process is going on we have a combined cloud effect which is called cirro-stratus. This form of cloud may be recognized, when looking off toward the horizon, by its being formed into long straight bands. It is sometimes called thread-cloud. As it further descends it takes on a different form called the cirro-cumulus, or curl-heap. This is just the opposite in its appearance to the cirro-stratus, as it is broken up into flocks of little clouds separated from each other and in the act of changing to the form of the cumulus, or billowy form of cloud; and this latter takes place when it drops to a still lower stratum of warmer air and is there called the cumulo-stratus, which is the form of cloud we most often see in the season of thunderstorms. The lower edge of the cloud is straight, parallel with the horizon, while the upper part is made up of great billowy masses, having high lights upon their well defined projections and blending into darker shades caused by the shadows in the valleys between the mountains of cloud. [Pg 76]

The rain cloud is called the nimbus, and may be said to be the extension of a cumulo-stratus. When it reaches this condition it is condensed to a point where the vesicular globules collapse and a number of them run together, forming a solid drop of water, and here it begins to fall. It may be very small at first, but in its fall other condensed globules will adhere to it and if the conditions are right, sometimes the rain drops will have the diameter of a quarter of an inch by the time they reach the earth.

Under other conditions, such as we have sometimes during dry weather, the rain drops will start to fall, but instead of growing larger, they grow smaller by absorption into the thirsty air, and will not be allowed to reach the earth. Often there are showers of rain in the air that fall to a certain distance and are taken up, as in the process of evaporation, to again be formed into cloud, without ever having touched the earth.

Thus it will be seen that clouds assume various forms under various conditions of atmosphere, as it is related to moisture, temperature, and density. Clouds sometimes appear to be stationary when they are only continually forming on one side and continually being absorbed into invisible moisture on the other. I remember seeing some wonderfully beautiful cloud effects in the regions of the Alps. Almost every day in summer there appears above the peak of Mount Blanc a [Pg 77] beautifully formed cloud cap standing some distance above it and hollowed out underneath like an inverted cup. Although this cloud appears to be stationary, it is undergoing a rapid change; the moisture rises from the snow-capped peak as invisible vapor to a certain distance, where it is condensed into a cloud of wonderful brilliancy. As the cloud globules float upward they are absorbed into the atmosphere again, as invisible moisture at the upper limit of the cloud. If the wind happens to be blowing, another phenomenon takes place, giving the appearance somewhat of a volcano. It is blown off from the peak in the direction of the wind, but within a short distance it strikes a warmer stratum of air, where it is absorbed and assumes the transparent condition.

If we ascend a high mountain, we get some idea of the altitude of the various forms of cloud. A thunderstorm may be in progress far below us, while the sun may be shining from a clear sky above, with perhaps the exception of the frost clouds that we have referred to floating high above the mountain tops.

We have now described in a general way how clouds are formed, how they are condensed into rain, and how moisture is distributed over large areas by these rain clouds being borne on the [Pg 78] wings of the wind; and now you ask, Whence the wind? In our next and following chapters we will try to answer this question.

CHAPTER X. [Pg 79]

WIND—WHY IT BLOWS.

We have said that globules of moisture, released by the action of the sun's rays in the process of evaporation, tend to rise because they are lighter than the air. Right here let it be said that all material substances have weight; even hydrogen, the lightest known gas, has weight, and is attracted by gravitation. If there were no air or other gaseous substances on the face of the earth except hydrogen, it would be attracted to and envelop the earth the same as the air now does. Carbon dioxide is a gas that is heavier than the air. If we take a vessel filled with this gas and pour it into another vessel it will sink to the bottom and displace the air contained in it until the air is all driven out. If we fill a jar with water up to a certain height and then pour a pint of shot into it the water will be caused to rise in the vessel because it has been displaced at the bottom by the heavier material. Now if we remove the shot the water will recede to the level maintained [Pg 80] before the shot was put in. On the contrary, if we should pour an equal bulk of cork or pith balls into the jar the water would not be displaced, because the balls are lighter than the water and would lie on top of it; if, however, the water is removed from the jar, the cork will immediately go to the bottom of the jar, because the cork is heavier than the air which has taken the place of the water. We wish to impress upon the mind of the reader the fact, that all substances of a fluidic nature, whether in the fluid or gaseous state, have weight, and obey the laws of gravitation, and the heavier portions will always seek the lower levels, and in doing this will displace the lighter portions, causing them to rise. There is no tendency in any substance to rise of itself, but the lighter substance rises because it is forced to do so by the heavier, which displaces it. This law lies at the bottom of all of the phenomena of air currents.

If we are at certain points on the seashore in the summer time we may notice that about 9 o'clock in the morning a breeze will spring up from the ocean and blow toward the land; this will increase in intensity until about 2 o'clock in the afternoon, when it has reached its maximum velocity, and from this time it gradually diminishes, until in the evening there will be a season of calm, the same as there was in the early morning. The explanation of this peculiar action of the [Pg 81] air is found in the fact that during the day the land is heated much more rapidly on its surface than the water is.

The radiant energy from the sun is suddenly arrested at the surface of the earth, which is heated to only a very shallow depth, while in the water it is different; being transparent it is penetrated by the radiant energy to a much greater depth and does not suddenly arrest it, as is the case on land. As the sun rises and the rays strike in a more and more vertical direction the earth becomes rapidly and intensely heated at its surface, and this in turn heats the stratum of air next above it, which is pressing on it with a force of fifteen pounds to the square inch at sea-level. When air is heated it expands, and as it expands it grows lighter. The stratum lying upon the earth as soon as it becomes heated moves upward and its place is occupied by the heavier, cooler air that flows in from the sides. We can now see that if there is a strong ascending current of air on the land near the ocean the cooler air from the surface of the ocean will flow in to take the place of the warmer and lighter air that is driven upward, really by the force of gravity which causes the heavier fluid to keep the lowest level. As the earth grows hotter this movement is more and more rapid, which [Pg 82] causes the flow of colder air to be quickened, and hence the increasing force of the wind as the sun mounts higher in the heavens. But when it has passed the point of maximum heating intensity and the earth begins to cool by radiation, the movements of air currents begin to slow up, until along in the evening a point is reached where the surface of the earth and that of the ocean are of equal temperature, and there is no longer any cause for change of position in the air.

The earth heats up quickly, and it also cools quickly, especially if there is green grass and vegetation. While they are poor conductors of heat, they are excellent radiators, so that when the sun's rays are no longer active the earth cools down rapidly and soon passes the point where there is an equilibrium between the land and water. The water possesses the opposite quality. It is slow to become heated, because of a much larger mass that is affected, and is equally slow to give up the heat. And the consequence is that after the sun has set, the land cools so much faster than the water that we soon have the opposite condition, and the sea is warmer than the land, which makes the air at that point lighter, and which in turn causes the denser or colder air from the land to flow toward the ocean, and displace the lighter air and force it upward; hence we have a land instead of a sea breeze. So that the normal condition in summer is that of a breeze [Pg 83] from the ocean toward the land during part of the day and a corresponding breeze from the land to the ocean during part of the night, with a period of no wind during the morning and evening of each day.

The forces that work to produce all the varying phenomena of air currents on different portions of the earth are difficult to explain, as there are so many local conditions of heat and cold, and these are modified by the advancing and receding seasons. The unequal distribution of land and water upon the earth's surface; the readiness with which some portions absorb and radiate heat as compared with others; the tall ranges of mountains, many of them snow-capped; the lowlands adjacent to them that become intensely heated under the sun's rays; the diversity of coastline and the fact that there is a zone of continually heated earth and water in the tropical regions—all these conditions, coupled with the fact that the earth rotates on its axis once in twenty-four hours, are certainly sufficient to account for all the complicated phenomena of aërial changes on the various portions of the earth's surface.

The trade winds are so called because they blow in a certain definite direction during certain seasons of the year, and can be reckoned upon for the use of commerce. If you trace the line of [Pg 84] the equator you will notice that for more than three-quarters of the distance it passes through the water. The water, as we have explained in the last chapter, becomes gradually heated to a considerable depth, and when once saturated with heat is slow to give it up. It can easily be seen that there will be a zone extending each way from the equator for a certain distance that will become more intensely heated than any other parts of the earth, with the exception of certain circumscribed portions of the land. The result is that this heated equatorial zone is constantly sending up warm air caused by the inrush of colder air, which is heavier than the air at the equator, expanded by the heat. The warm air at the equator is forced up into the higher regions of the atmosphere, and here it overflows each way, north and south, causing a current of air in the upper regions counter to that of the lower. As it travels north and south it gradually drops as it becomes cooler, and finally at some point north and south its course is changed and it flows in again toward the equator. As a matter of fact, the trade winds do not flow apparently from the north and south directly toward the equator, but in an oblique direction. On the north side of the equator we have a northeasterly wind, and a southeasterly wind on the south side. This is caused by the rotation of the earth from west to east. The direction of the trade wind, however, is more [Pg 85] apparent than real.

The earth in its diurnal revolutions travels at the rate of a little more than 1000 miles an hour at the equator. But if we should travel northward to within four miles, say, of the north pole, the surface point would be moving at the rate of only about a mile an hour. At some point equidistant between the north pole and the equator the surface of the earth will be moving at a rate, say, of 500 miles an hour. If we could fire a projectile from this point that would have a carrying power to take it to the equator some time after the projectile was fired, although it would fly in a perfectly direct line, it would appear to anyone at the equator who observed its approach to be moving from a northeasterly direction. The reason is that the earth is traveling twice as fast at the equator as it is at the point whence the projectile is fired. Therefore it will overshoot, so to speak, at the equator, and not be dragged around by the increased motion we find there.

To make this still plainer, suppose the earth to be standing still and a projectile be fired directly across from the north pole in the direction of the lines of longitude and required one hour to reach the equator, the projectile would appear to anyone standing at the equator to come directly from the north. If, however, the earth is revolving at the rate of 1000 miles an hour at the [Pg 86] equator to the eastward, and the projectile was fired from the pole, where there is practically no motion, in the same direction along the longitudinal lines as before, the observer would have to be in a position on the equator 1000 miles west of this longitudinal line in order to see the projectile when it arrived; therefore the apparent movement of the projectile would not be along the line at the instant that it was fired, but along a line that would cross the equator at a point 1000 miles west. When a southward impulse is given to the air it follows, to some extent, the same law, so that to one standing on the equator the northern trade wind will blow from the northeast and the southern trade wind from the southeast.

Owing to the fact that the air rises in the heated zone there is always a region of calms at this point where there is no wind and no rain. There are two other regions of calms in the ocean, one at the north at the tropic of Cancer and another at the south near the tropic of Capricorn. As has been stated, there are currents flowing back in the upper regions at the equator north and south, and these are called the upper trades—the lower currents being called the lower trades. These upper trades gradually fall till they reach the tropic of Cancer on the north, where the lower part of the current stops and bends back toward the equator, now becoming a part of the lower trade [Pg 87] wind. This causes a calm at that point where it turns. The upper parts of this current continue on, in a northerly and southerly direction, on the surface until they meet with the cold air of the north and south polar regions, where there is a conflict of the elements—as there always is when cold and warm currents meet.

The only point where the trade wind has free play is in the South Indian Ocean, and this is called the "heart of the trades."

If the whole globe were covered with water there would be a more constant condition of temperature; but owing to the great difference between the land and water, both as to altitude and the ability to absorb and radiate heat, we have all of these varied and complicated conditions of wind and weather. The trade winds shift from north to south and vice versa with the advancing and receding seasons, due to the fact that the earth has a compound motion. It not only revolves on its axis once in twenty-four hours, but it rocks back and forth once a year, which is gradually changing the direction of its axis; and in addition to these motions it is traveling around the sun as well.

[Pg 88]

CHAPTER XI.

WIND—CONTINUED.

In our last chapter we discussed the winds that prevail in the regions of the tropics called trade winds, because they follow a direct course through the year, with the exceptions noted in regard to their shifting to the north or south with the changing seasons; we also described the phenomena of land and sea breezes, which during certain seasons of the year reverse their direction twice daily. We will now describe another kind of wind, called monsoons, that prevail in India.

India lies directly north of the great Indian Ocean, and the lower part of it comes within the tropical belt lying south of the Tropic of Cancer. During the summer season here the earth stores more heat during the day than it radiates or loses during the night. This causes the wind to blow in a northerly direction from the sea both day and night for six months each year, from April to October. During these months the land is continually heated day and night to a higher temperature than the water in the ocean south of it. The winds are probably not so severe during the night as through the day, as the difference between the temperature of the land and the [Pg 89] water will not be so great during the night; and difference of temperature between two points usually means a proportional difference in the velocity of the wind. There is a time in the fall and spring, while there is a struggle between the temperature of the land and water for supremacy, when the winds are variable, attended with local storms somewhat as we have them in the temperate zone. But after the sun has moved south to a sufficient extent the land of India loses more heat at night than is stored up in the day; hence the conditions during the winter months are reversed, the water is constantly warmer than the land, and there is a constant wind blowing from the land to the ocean, which continues until April, when after a season of local storms the conditions are established in the opposite direction. These winds are called "monsoons."

The word monsoon is probably derived from an Arabic word meaning "seasons." It is a peculiarity of this monsoon that in summer it blows in a northeasterly direction from the sea and in the winter in a southwesterly direction from the land. This divergence from a direct north and south is caused by the rotation of the earth and the explanation is the same as that we have given for the trade winds.

In the southern latitudes there is a comparatively constant condition of wind and weather, [Pg 90] because the surface of the globe in these regions is mostly water; but in the north, where most of the land surface is located, we have a very different and a very complicated set of conditions, as compared with the southern zones.

The freaks of wind and weather that we find prevailing upon the North American continent are not so easily accounted for as the phenomena heretofore discussed. In the northern part the land reaches far up toward the north pole, while on the west lies the Pacific Ocean, which merges into the Arctic Ocean at Bering Strait. The climate of the western coast is affected by a warm ocean current that sets up as far north as Alaska, while high ranges of mountains prevent the effects of this warm current from being felt inland to any great extent; all of which helps to complicate any theory that may be advanced regarding changes of weather. Aside from the changes of temperature that are due to the seasons, which are caused by the oscillating motion of the earth between the limits of the Tropic of Cancer on the north and the Tropic of Capricorn on the south, there are other changes constantly taking place in all seasons of the year. While it is not difficult to account for the change of seasons and the gradual change of temperature that would naturally follow—owing to the difference of angle at which the sun's rays strike the earth—it is more [Pg 91] difficult to account for the violent changes that occur several times during the progress of a season, as well as the less violent ones that come every few days. In fact, it rarely happens that the temperature is exactly the same on any two successive days during the year. The diurnal changes are easily accounted for by the rotation of the earth on its axis each day. But there is another class of phenomena with which the "weather man" has to struggle when he is making up a forecast of the weather from day to day.

In order that we may proceed intelligently, let us say a word about the barometer. We speak of high and low barometer, and we make the instrument with graduations marked for all kinds of weather, which really mean but very little. The reading of a single barometer alone will give us but a faint idea of what is really going to happen from day to day. But if we have a series of barometers located at different stations scattered all over the continent and connected at headquarters by telegraph, so that we can have the readings from a whole series of barometers at once, then it becomes a very useful instrument. A barometer may read low at one station by the scale, but may be high with reference to some other barometer that reads very low. [Pg 92]

What is a barometer? If we should take a glass tube closed at one end, the area of the cross section of which is one inch square, and fill it with mercury, and while thus filled plunge the open end into a vessel of mercury, it will be found that the amount of mercury remaining in the tube above the level of the mercury in the vessel will weigh about fifteen pounds, if the experiment has been performed at sea-level. This will vary, however, according to the temperature of the air. Of course barometers are tested when the air is at a certain temperature. If the weight of mercury in the tube is fifteen pounds, since it is sustained by the air pressing down on the mercury in the open vessel, it shows that the air-pressure on that open vessel is equal to fifteen pounds to the square inch. In practice, of course, the tubes are made very much smaller. If the air changes so that it is lighter than normal the mercury will fall in the tube, because the pressure on the mercury in the open vessel is less than fifteen pounds to the square inch. And, again, conditions may arise that will condense the air and make it for the time being weigh more than fifteen pounds to the square inch, in which case the mercury will rise in the tube. Thus it will be seen that the barometer will register the slightest change in air pressure.

Let us dwell for a moment on the causes of what are commonly called "changes of weather," [Pg 93] when we will again revert to the use of the barometer.

The use of the telegraph in connection with the establishment of a weather bureau having stations for observation at convenient points throughout the country has contributed much to the science of meteorology. It is found that there are areas of high and low pressure existing at the same time in different parts of the country. These usually have their origin in the far northwest, and follow each other, sweeping down the eastern side of the Rocky Mountains and gradually bending easterly and from that to northeasterly by the time they reach the Atlantic coast. The areas of low pressure are called cyclones, while the areas of high pressure are called anti-cyclones. (By cyclone we do not mean those cloud funnels commonly called by that name that form at certain times of the year in certain sections of the country and produce such destruction of life and property. These storms are usually confined to a narrow strip and are short-lived. They arise undoubtedly from local conditions. A description of these tornadoes—for such is their true name—will be given in some future chapter.)

These centers of high and low pressure may be several hundred miles apart. In the area of high pressure, if it is in the winter season, the weather is unusually clear and cold, and generally clear [Pg 94] and fairly cool at any season, and while there may be some wind it is not so strong as in the cyclone or low-pressure center. At this point it will be warmer and winds will prevail, with rain or snow, the winds varying in direction and intensity at a given point as the cyclone moves forward. In the center of these cyclones and anti-cyclones there will be a region of comparative calm, and the air is ascending at the center of the area of low pressure while it is pouring in on all sides from the area of high pressure where the air is compressed by a downward current from the upper regions.

The high-pressure or anti-cyclone system usually covers a larger area than the low-pressure system, where the air is ascending. While the air moves laterally from high to low, it does not move in a direct line. The air movement outside of the high-pressure center is usually not at a very high speed, but in northern latitudes in the direction of the hands of a clock. As it circles around it widens out spirally until it reaches the edge of a low-pressure system, when it bends in its course and moves in the other direction around this center, but constantly moving inward toward it in a spiral form and in a direction that is reverse to that of the hands of a clock. When the air current comes within the influence of a low-pressure or cyclonic system the velocity of its [Pg 95] movement is very much accelerated until it has moved into the zone of quiet air in the center, where it is ascending.

In the upper regions of the atmosphere there are counter currents flowing in the opposite direction. The downward flow at the area of high pressure compresses the air near the surface of the earth and rarefies it in the higher regions of the atmosphere, while the opposite effect is going on over the center of low pressure, the air being rarefied nearer the surface of the earth, but condensed above normal in the higher regions by the upward current, which causes an overflow back toward the rarefied upper regions over the area of high pressure.

It will be observed that the ordinary storm has a compound motion. The whole system moves in an easterly direction, while the winds are blowing spirally about the storm center. If we should be in the track of a moving storm so that its center passed over us the winds at the beginning would blow in one direction and then there would come a subsidence until it had moved forward through the quiet zone, when we should feel the wind in the opposite direction until the area of low pressure had moved forward into the region of high pressure. The velocity of the wind will be determined by the difference of pressure between the areas and by the distance that the areas of [Pg 96] high and low pressure are apart. The steeper the grade the more rapidly the fluid will flow.

Let us now have recourse, for a moment, to Figs. 1, 2, and 3 in order that the subject may be more fully understood. In looking at these diagrams we should imagine ourselves looking South, with the left hand to the East.

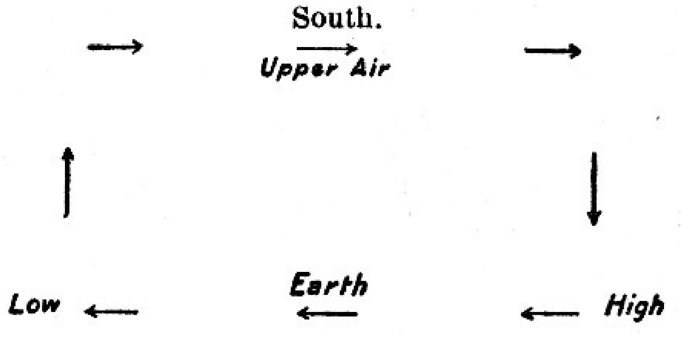

Fig. 1.

Fig. 1 shows the general direction of the air movement between two areas—one of high and the other of low pressure. The arrows show the general direction of the wind. You will notice that in the upper regions it blows in an opposite direction from the air movement on the surface of the earth.

Fig. 2 shows in a general way how the wind moves spirally around both centers. Over the area of high pressure the air descends spirally from the upper regions, circling around a large area—it may be one hundred miles or more in diameter—in the direction of the movement of the hands of a clock. [Pg 97]

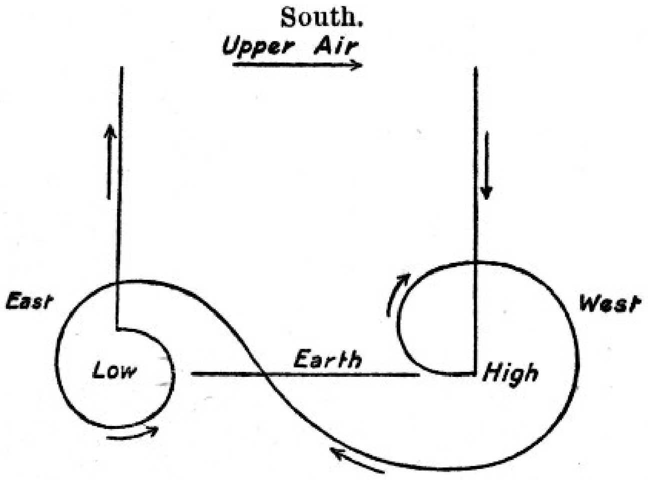

Fig. 2.

But then the wind at the high-pressure area is lighter than it is at the low, and circles outwardly until it finally moves off in the direction of a low-pressure area, gradually bending in the other direction until finally it moves the reverse of the hands of a clock—although now it is in a smaller circle, and with a more rapid motion. It moves spirally and upwardly about the low-pressure area until it reaches a point in the upper air, where it goes through the same gyrations in an opposite direction. Now imagine the whole combination moving from west to east at an average rate of thirty miles per hour, and imagine further that this system is linked to other systems that are following along, and you have some idea of the weather changes as they occur in the middle United States. [Pg 98]

By referring to Fig. 3 you will see why the wind changes its direction when a storm center passes over any point. It has not only a spiral but also a forward movement.

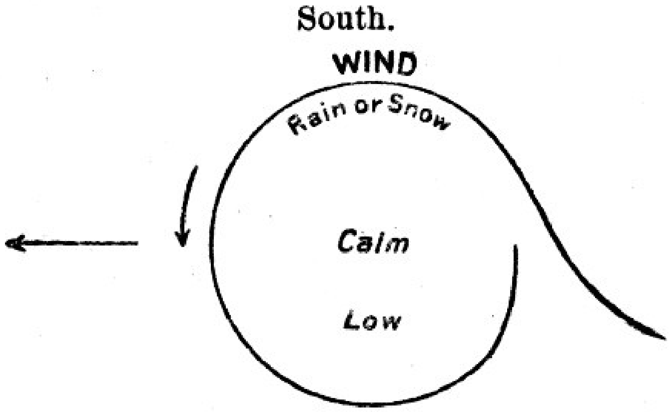

Fig. 3.

Now let us go back to the barometer and see what part it plays in predicting changes in the weather. At the area of low pressure the air is ascending, as we have seen, and, owing to the peculiar way it ascends—by circling spirally upward around a region of comparative calm—it creates a partial vacuum, which is more pronounced in the center of the area. At the area of high pressure the air will be condensed by the descending current being arrested by the earth. The descending current—coming, as it does, from the upper and colder regions—accounts for the cool weather that most always prevails at a high-pressure area. In order to know how great the change of weather is likely to be, we must know what the readings of at least two barometers are —one at the high- and another at the low-pressure area. [Pg 99] If the difference between the readings of the two barometers is very great, and the areas are comparatively close together, we may expect the change to be sudden and violent.

"High" and "low" as applied to a barometer are only relative terms. There is no fixed point on the index of the instrument that can be said to be arbitrarily high or low. For this reason a single barometer is not of much use. If it begins to fall from any point, and falls rapidly, it indicates that an area of a much lower pressure is approaching. The same is true of a high-pressure area, if the barometer rises rapidly from any point.

If we study the air motions in these systems sufficiently to get at least an inkling of the law of their movements, it becomes a very interesting subject.

Wind from whatever cause serves a wonderfully useful purpose in the economy of nature. Without wind, heat and moisture could not be distributed over the face of the earth and our globe would not be a fit habitation for man. How wonderful is the machinery of Nature, that can first forge a world into shape and afterward decorate it with green grass and flowers that are watered by the "early and latter rain"!

CHAPTER XII. [Pg 100]

LOCAL WINDS.

There are so many causes that will produce air motion that it is often difficult to determine just what one is the chief factor in causing the direction of the wind at any particular time. There are very many instances, however, where the cause can be traced without difficulty; many of these have already been mentioned and there are many more that might be. Of course, as has been often stated, there is only one remote cause for all winds, and that is the sun, coupled with the movements of the earth. But there are certain local conditions that are continually modifying the phenomena of air movement. The velocity of winds as they occur from day to day varies very greatly with the height above the surface of the earth; ordinarily the velocity at 1000 feet above the earth will be more than three times greater than it is at 50 or 60 feet above, and even at 60 feet the velocity is much greater than at the surface of the earth. This is due partly to the retarding effect of friction caused by contact of the air with the earth's surface, but more [Pg 101] particularly by trees, inequality of surface, and other obstructions on the earth.

There is a variety of wind called mountain winds that arise from different causes. As has been stated in a former chapter, under ordinary conditions the air is more dense at sea-level than at any point above, and the density is constantly changing from denser to rarer the higher we ascend. Suppose at a certain point, say halfway up a mountain side, the air has a certain density, and if it is at rest the lines of equal density or pressure will seek a level, just as water would under the same conditions. Suppose we start at a given point on the side of a mountain and run out on a level till we are 100 feet in a perpendicular line above the side of the mountain, the air contained within those lines will be in the shape of a triangle. If now the sun shines upon the side of the mountain the air is warmed and expands according to a well-known law, and the amount of expansion will depend upon the depth of the volume of air; hence the point of greatest expansion in our figure will be where the air is 100 feet deep, and will gradually decrease as we go toward the mountain till we come to the point where our horizontal line makes contact with the mountain side. At that point, of course, there is no expansion, because there is no depth of air; and the [Pg 102] effect will be that the expanded air will overflow toward the mountain, and be deflected up its sloping side. If we apply this same principle to the whole mountain side we can see that there will be, during the day, a constant current of air flowing up the mountain. As night comes on this upward movement will cease and there will be a season of quiet until the earth has become colder than the air, and we have a phenomenon of exactly the opposite kind, when the air contracts instead of expands, which produces a downward current from the mountain top.

These currents are as regular at certain seasons of the year as the land and sea breeze. Of course, they may be obliterated for the time being, by the presence of a stronger wind due to some other cause, such as during the prevalence of a storm. In some of the regions of California hottest during the day time, the nights are made endurable, and even delightful, by the cool breezes that sweep down from the tops of the mountains. It often happens that on the shady side of a high and steep mountain where the sun's rays strike it so obliquely, if at all, that the earth will be but little heated, there will be a vast mass of cold air stored up. After the valley has become intensely heated by the sun there is an ascending current of air which in turn causes a down rush of the cold body of air from the mountain side. These local winds are frequently very [Pg 103] severe, only lasting, however, for a short time, until an equilibrium of temperature and density has been established. A wonderful exhibition of this sort of wind is said to occur at certain times of the year on the coast at Tierra del Fuego, where a blast which they call the "Williwaus," comes down from the mountain side, without warning, with such tremendous force that no ship could stand the strain if it should continue for any length of time. Fortunately the shock does not last more than eight or ten seconds, when it is followed by a perfect calm. It is as though a great volume of air had been fired from some enormous cannon from the top of the mountain to the sea. The water is pulverized into a spray that is driven in every direction.

Sometimes these violent blasts occur in the Alps, but from a very different cause. Avalanches of great extent often take place on the sides of the mountains, when a vast amount of material, equal to three or four hundred million cubic feet of earth, will fall several thousand feet. Often an avalanche of this kind will produce a wind, which is confined, of course, to a restricted area, that is said to be so violent as to tear one's clothes into shreds. This is not caused by any difference of temperature, but by a violent compression. [Pg 104]

There is a peculiar wind that occurs in Switzerland, often, between the months of November and March. These winds last from two to three days and are of great violence—especially near the mountains. They are warm and dry and are caused by an area of low barometer and an ascending current of air occurring at some point north of the Alps, which causes the air from Italy to flow over the Alpine range, causing a tremendous precipitation of snow and rain, which not only takes the moisture from the air, but sets free in the form of heat the energy that was stored in the process of evaporation, and this, together with the compression of the air as it flows down the slope of the mountains, makes it hot and dry. This wind is called the "Fohn."

There is a similar condition of things existing on the eastern slope of the Rocky Mountains which has a modifying effect upon the climate of parts of Colorado, Wyoming, Montana, also extending up into British America. This wind, which is here called "chinook," arises from causes similar to those that are active in Switzerland that give rise to the "fohn" wind.

There is a wind called the "blizzard" that is felt most keenly in Montana and the Dakotas during the winter, which is exceedingly cold and lasts sometimes for a period of 100 hours. The [Pg 105] temperature falls at times 30 or 40 degrees below zero and the wind maintains a velocity of from forty to fifty miles an hour. These winds spread eastward as far as Illinois, but not with the same severity, and they move southward to the Gulf of Mexico, spreading over the States of Texas and Louisiana, and are there called "northers." It is exceedingly dangerous to be caught in a blizzard in the Dakotas, where the wind reaches its greatest velocity and the cold its lowest temperature —especially when the wind is accompanied, as it frequently is, by severe snowing. By the time it reaches the Gulf States it is very much modified as to temperature, but it is a very disagreeable wind in that portion of the country, because of the exceeding dampness of the air. One would be much more comfortable in dry, still air, even if it were many degrees below zero, than in an air freighted with moisture, although the temperature has not fallen to the freezing point.

There are hot winds called by different names according to the localities in which they occur. In southern California at certain seasons of the year the inhabitants are afflicted with what they call a desert wind that blows from the heated regions of Arizona toward the Pacific Ocean. The temperature sometimes reaches 120 degrees Fahrenheit, and persons have been known to perish from the effects of these hot winds in open boats out on the water before they could reach land. [Pg 106]

Hot winds prevail on the plains of Kansas during the months of July and August that are phenomenal in their intensity, so much so that if they were widespread and of long continuance, like the northern blizzard, they would be attended with great loss of life and destruction to vegetation. Fortunately, they come in narrow streaks and in most cases do not blow more than from ten to thirty minutes at a time. These hot belts are sometimes not over 100 feet wide, and again they are as much as 500. They are so hot and dry that green leaves and grass are rendered as dry as powder in a few minutes. These winds are probably caused by the fact that at this season of the year, when the prevailing wind is southwesterly, the air becomes heated to a great height, and are the resulting effect of certain combinations of air currents in the higher regions of the atmosphere that force the already heated air toward the earth. As the air descends it is more and more compressed, which causes it to become more and more heated. We have already described the heating effect of compression upon air as shown by the experiment with the fire syringe. It was shown that air at normal temperature could be suddenly compressed into so small a space that the condensed heat, which was before diffused through the whole bulk of air at [Pg 107] normal pressure, was sufficient to cause ignition. A cubic yard of air on the surface of the earth would occupy a much larger space if carried a mile above it. From this it is easy to see that if a volume of air at that height had a temperature of 70 or 80 degrees it would be very hot when condensed into a very much smaller volume, as it would be if it were forced down to the surface of the earth. These winds are the result of some superior force that is active in the upper regions of the atmosphere, because it is natural for heated air to rise, and this is what happens when the power that forced it down to the earth is no longer active to hold it there.

Reference has been made in a former chapter to tornado winds; they are rather exceptional phenomena and not thoroughly understood. The winds seem to blow in from all directions toward an area of very low pressure at a single point. The spiral motion that is common to all cyclones, in a tornado seems to be gathered up into a condensed form, like a funnel. The direction of movement is the same as that of the cyclone—that is, in the reverse direction to that of the hands of a watch. The upward motion of the air inside of the funnel is at a rate of over 170 miles an hour. The onward movement of the whole system is about thirty miles per hour. [Pg 108]

Tornadoes occur with greater frequency in the United States than in any other section of the globe. Tornadoes seldom occur in winter, except perhaps in the Southern States. They are more frequent in the month of May than at any other time during the year, although they occur sometimes in April, June, and July.

Between 1870 and 1890 about sixty-five destructive tornadoes occurred in the United States, involving great loss of life and property. When a tornado moves off the land on to the ocean it may become what is termed a waterspout. These probably never originate on the water, but after they have once formed may be carried over the water to a considerable distance. A tornado was never known to originate on the shores of Lake Michigan, but there are a few instances (the most notable one being the Racine tornado) when they have reached the lake after having traveled from some distant point inland.

The Racine tornado—so called because it destroyed a large portion of that city—happened fifteen or more years ago. The tornado originated about 100 miles southwest of Racine, Wis., in northern Illinois. The funnel-shaped cloud passed over the lake, but the tornado character of the storm was broken up before it reached the other shore.

When a tornado passes from land to water it becomes a waterspout only when the cloud-funnel [Pg 109] hangs low enough and the gyratory energy is sufficiently great. There is a great pressure on the water outside of the funnel and almost a perfect vacuum inside. This latter fact contributes largely to the destructive power of the tornado. When a funnel is central over a building a sudden vacuum is created outside of it and it bursts outwardly from the internal air pressure.

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CHAPTER XIII.

WEATHER PREDICTIONS.

To predict with any great accuracy what the weather will be from day to day is a somewhat complicated problem, and, as all of us have reason to know, weather predictions made by those who have the matter in charge and are supposed to know all about it often fail to come to pass. The real trouble is that they do not know all about it. There are so many conditions existing that are outside of the range of barometers, thermometers, anemometers, and telegraphs that no one can tell just when some of these unknown factors will step in to spoil our predictions.

In very many cases, perhaps in a large majority of them, the predictions made by the weather bureau substantially come to pass. It has been stated in former chapters that the changes of weather accompany the movements of what are called cyclones and anti-cyclones, the cyclone being accompanied by low barometric pressure and the anti-cyclone by a higher one. The winds of the cyclone move spirally around the center of lowest depression with an upward trend, the [Pg 111] motions being in a direction reversed to that of the hands of a clock. In the centers of high pressure the current is downward instead of upward and the direction of the wind around it is opposite to that around the low-pressure area. The fundamental factor in predicting the weather is the direction of movement of these areas of low pressure. In almost all cases the direction of movement is from the west to the east, but not always in a straight line. These movements, however, are classified so that after the direction has become established one can predict with considerable accuracy as to whether it will move in a curved or a straight line. By movement we do not refer to the direction of the wind at any particular point, but the onward movement of the whole cyclonic system, which is usually from twenty-five to thirty miles an hour, but in some cases the speed is much greater.

Not only does the upward movement of the whole system vary, but the velocity of the wind around any given cyclonic center varies. There are about eleven classes of cyclones that appear in the United States, each class having its own path of movement and origin. A large number of these appear to originate north of the Dakotas, and move directly east to the Gulf of St. Lawrence. Three other classes originate on about the same line, a little west,—say, north of [Pg 112] Montana,—moving first in a southeasterly direction, passing over the center of Lake Michigan and bending northerly through Lake Ontario and finally landing in the Gulf of St. Lawrence. Two other classes start at the same point, one of them going as far south as Cincinnati, and the other as far south as Montgomery, Ala., and both turning at these points northeasterly to the Gulf of St. Lawrence. Two other classes originate in Colorado, one moving in a northeasterly direction slightly curved, and the other directly east. Still others have their origin farther south in the Gulf of Mexico, and move in a northeasterly direction. Very rarely they originate in the Atlantic east of Savannah, moving first in a northwesterly direction, but finally bending to the northeast.

Every day there is a weather map made up showing the locations of the high and low barometers, direction of wind, lines of equal pressure, as well as those of temperature. By study from year to year all of these phenomena have become systematized, so that by tracing an area of low barometer from its origin in its progress easterly it is soon seen to fall under one of these classes and we are able to predict about what its course will be. Knowing the speed of its movement as well as the velocity of wind and all the conditions attending it, taken in connection with the [Pg 113] weather conditions in the region for which the prediction is made, an expert can ordinarily forecast with some degree of accuracy. After all that can be said, however, weather predictions based upon maps are and have been far from satisfactory. One who has been a close student of local conditions for a number of years will often predict with as great accuracy as the weather bureau. Areas of low pressure are followed sooner or later by a fall of temperature; this is especially true in the winter months. Sometimes this fall is very marked, and then it is called a cold wave. These sudden changes of temperature are not thoroughly understood, but are supposed to be due partly at least to rapid radiation of heat into the upper regions, as the clear atmosphere which usually attends areas of high pressure is favorable to such a condition. Undoubtedly, too, there are dynamic causes, forcing the colder air from the upper regions to the earth, when it immediately flows off toward an area of low barometer.

Long-time predictions are purely guesses. They sometimes guess on the right side, and this gives them courage to make another. It is an old saying that "all signs fail in dry weather." In time of a drought it is true that the indications which at ordinary times would be surely followed by a rain are of no value. When a season is once established, either as a rainy season or a dry season, it is [Pg 114] likely to persist in this character until a change comes that is produced by the movement of the sun in its course northerly and southerly, and the change produced from this cause requires several weeks of time.

If accurate weather predictions could be made for a long time in advance, or for even a week, they would be of incalculable value. But it is doubtful if ever this will be brought about, as there are too many necessarily hidden factors which enter into the calculations. If stations could be established all over the oceans with sufficient frequency, and an equal number at a sufficient altitude in the air, I have no doubt that much that is now mysterious might be made plain.

CHAPTER XIV. [Pg 115]

HOW DEW IS FORMED.

Reader, did you ever live in the country? Were you ever awakened early on a summer's morning to "go for the cows"? Did you ever wade through a wheat field in June—or the long grass of a meadow—when the pearly dewdrops hung in clusters on the bearded grain, shining like brilliants in the morning sun? Have you not seen the blades of grass studded with diamonds more beautiful than any that ever flashed in the dazzling light of a ballroom? If not, you have missed a picture that otherwise would have been hung on the walls of your memory, that no one could rob you of.

Everyone has noticed that at certain times in the year the grass becomes wet in the evening and grows more so till the sun rises the next day and dispels the moisture, and this when no cloud is seen. Dew is as old as the fields in which grass grows. It was as familiar to the ancients as it is to us, and yet it is only about three-quarters of a century since the cause of it has been understood. [Pg 116] We even yet speak of the dew "falling" like rain. In former times some scientists supposed that it was a fine rain that fell from the higher regions of the atmosphere. Others supposed it to be an emanation from the earth, while still others supposed it was an exudation from the stars.

> "By his knowledge the depths are broken up and the clouds drop down dew" (Prov. iii. 20).

The first experiments carried on in a scientific way were by Dr. Wells, a physician of London, between the years 1811 and 1814.

Everyone has noticed in warm weather the familiar phenomenon of water condensed into drops on the outside of a pitcher or tumbler containing cold water. This condensation is dew. It always forms when the conditions are right, summer and winter. In cold weather we call it frost. It has been stated in a former chapter on evaporation that the capacity of the air for holding moisture in a transparent form depends upon its temperature. If the temperature is at the freezing point it will contain the 160th part of the atmosphere's own weight as aqueous vapor. If it is 60 degrees Fahrenheit the air will retain six grains of transparent moisture to the square foot of air, while at 80 degrees it will contain nearly eleven grains. When the air is charged with this vapor to the [Pg 117] point of saturation (which point varies with the temperature) a slight depression of the temperature is sufficient to condense this vapor into cloud or drops of water. Between 1812 and 1814 Dr. Wells made a series of experiments with flocks of cotton wool. He weighed out pieces of equal weight and attached a number of them to the upper side of a board and as many more to the lower side, and exposed it to the night air under varying conditions. One experiment was made with a board four feet from the earth, so that half of the bunches of cotton faced the ground and the other half the sky. He found upon weighing these after a night's exposure under a clear sky that the cotton wool on top of the board had gained fourteen grains in weight from the moisture, or dew, that had formed upon it, while the same amount of cotton on the under side of the board had only increased four grains. He tried further experiments by making little paper houses, or boxes, to cover a certain portion of grass or vegetation. He found that while there would be a heavy dew on the grass outside there was little or none within the inclosure. These experiments were conducted in various ways and closely watched to see that none of the phenomena were in any way connected with falling rain. It has been determined that substances like grass and green leaves of all kinds, hay and straw, while they are poor conductors of heat, [Pg 118] are excellent radiators. In another chapter we have referred to this quality of straw, that is taken advantage of by the inhabitants of hot countries in the manufacture of ice and in our own land for storing it.

Perhaps everyone who has lived in the country has noticed that on a summer's morning when the grass is laden with dewdrops a gravel walk or a dusty road will be perfectly dry. This is due to the fact that the gravel will retain heat and not radiate it, for a much longer time than grass or green leaves. Dew begins to form upon the grass very soon after the sun is set because the moment the sun's rays are withdrawn the heat is rapidly radiated by the blades of grass, which cools the earth under it and the air above and surrounding it, so that if the air is anywhere near the moisture saturation point on cooling at the surface of the ground it will readily give up a part of its moisture, which condenses in drops upon the blades of grass.

If the night is still and clear and there is much moisture in the air, the dew will be heavy, but if the night is cloudy there will be little or no dew formed. The clouds form a screen between the earth and the upper regions of the atmosphere, which prevents the heat from radiating to a sufficient extent to form dew. For the same reason no dew will form under a light covering [Pg 119] spread over the ground even at some distance above it. The covering acts as a screen, which prevents the heat from radiating to the dew point. From what has gone before it will be seen that if the atmosphere is not charged with moisture up to the point of saturation it will require a greater amount of depression of temperature to cause condensation, and this is why we usually have heavier dews in June when the air is more highly charged with moisture than we do in August when it is dry. This also accounts for the ice clouds, called cirrus, being formed so high up in the atmosphere during dry weather. There is so little moisture in the air that it requires a very great difference of temperature to cause condensation to take place, and the necessary depression is not reached in these cases except at an altitude of several miles.

Dr. Wells has shown that if we take the reading of two thermometers on a clear summer night, one of them lying on the grass and the other suspended two feet above it, we shall find that the one lying on the grass will read 8 or 10 degrees lower than the one suspended in the air. If the night is still there will be a cold stratum of air next to the earth, which will not tend to diffuse itself to a very great degree and dew will form. If, however, it is cloudy or the wind is blowing there is rarely any formation of dew. The reason in the former case, as we have explained, is that [Pg 120] the radiated heat is held down to the earth in a measure, and in the latter case there is a constant change of air; so that in either case no part of it is allowed to cool down sufficiently to precipitate moisture.

It is a curious fact that often there will be a heavier dew under the blaze of a full moon on a clear night than at any other time. The moon has no screens about it of any kind to obstruct the free radiation of heat. It is supposed to be a dead cinder floating in space and not surrounded by an atmosphere, so that the sun's rays have full effect upon it during the time it is exposed to them, and at that time it becomes heated to a temperature of something like 750 degrees Fahrenheit. For half the month, say, the sun is shining continuously upon all or a part of it. In other words, the days and nights of the moon are about two weeks long. The moon does not revolve upon its own axis like the earth, therefore the same side or a portion of it is exposed to the sun for 14 days. During the time that the moon is in the earth's shadow it is supposed to fall to 187 degrees below zero, which is 219 degrees below the freezing point. When the moon is full and is heated up to over 700 degrees there is sufficient heat radiating from it to be felt sensibly upon the face of the earth, and it would be felt if it were not for the great envelope of atmosphere and its [Pg 121] attendant cloud formations that surround the earth. There are but few days in summer when there is not a haze in the atmosphere, although we call the sky clear, which intensifies the light and gives everything a warmer tone. The heat coming from a full moon on a clear night is absorbed in causing the aqueous vapors that are partly condensed in the higher regions of the atmosphere, to be reabsorbed into transparent vapor. This clears away the heat screen in the atmosphere and allows radiation to go on more rapidly at the earth's surface, and thus cools it to a greater extent when the moon is shining brightly than when it is dark and in the shadow of the earth.

As we have already mentioned, the cold that is produced by radiation through the blades of grass and other radiating substances may be indicated by placing one thermometer on the ground and fixing another at some point in the air. Sometimes the difference is very marked, amounting to as much as 20 or 30 degrees. If under these conditions a cloud floats overhead, forming a heat screen, its presence will be readily noticed by a rise in the thermometer. Radiation into the upper regions of the atmosphere is checked, which causes a sudden rise in the temperature near the surface of the earth. By taking advantage of this principle of heat radiation from the earth's [Pg 122] surface it is a very easy matter to protect tender vegetation from even quite a severe frost, if it occurs in the early fall, by a slight covering, such as thin paper. The paper will act as a heat screen and in a measure prevent the heat from radiating from the earth immediately under it. Frost—which of course is but frozen dew—at this season of the year will form on a still autumn night, although the atmosphere at some distance above the ground is some degrees above the freezing point. The reason for this will be obvious when we consider the facts that have been set forth concerning the power of radiation to produce cold.

It has been estimated by meteorologists that the amount of water condensed upon the surface of the earth in the form of dew amounts to as much as five inches, or about one-seventh of the whole amount of moisture that is evaporated into the air. It will thus be seen that dew performs an important part in supporting vegetation.

The same operation in nature's great workshop that forms the dews of summer creates the frosts of winter. The moisture in cold weather is condensed the same as in warm. When it is condensed at the surface of the earth we have the phenomenon of frost, but when condensed in the upper regions of the atmosphere we have that of snow. [Pg 123]

Heat radiation from the earth goes on in winter, which is evidenced by the fact that a thick covering of snow is a great benefit to vegetation as a protection against the injurious effects of frost. The writer has seen flowers blooming abundantly at an altitude of 12,000 feet above the sea-level, protected only by the friendly shelter of a snowbank. In some cases the blooming flowers were in actual contact with the snow. By experiment it has been determined that the earth under a thick coating of snow is usually warmer by nine or ten degrees than the air immediately above the snow covering.

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CHAPTER XV.

HAILSTONES AND SNOW.

A hailstone is a curious formation of snow and ice, and most of the large hailstones are conglomerate in their composition. They are usually composed of a center of frozen snow, packed tightly and incased in a rim of ice, and upon this rim are irregular crystalline formations jutting out in points at irregular distances. Frequently, however, we find them very symmetrically formed as to outline, and the snow centers are almost without exception round. Hailstones and hailstorms differ in different climates, but they are more pronounced in the torrid than in the temperate zone. Historians give accounts of hailstones of enormous size; the very large hailstones being undoubtedly aggregations of single stones that have been thrown together and congealed in the clouds during their fall to the earth.

It is recorded that on July 4, 1819, hailstones fell at Baconniere measuring fifteen inches in circumference, and very symmetrically formed, with beautiful outline. Hailstones in India are said [Pg 125] to be very large—from five to twenty times larger than those in England or America—seldom less than walnuts and often as large as oranges and pumpkins. It is recorded that in 1826, during a hailstorm at Candeish, the stones perforated the roofs of houses like cannon shot, and that a single mass fell that required several days to melt, weighing over 100 pounds. It is further recorded that on May 8, 1832, a conglomerate mass of hailstones fell in Hungary a yard in length and nearly two feet in thickness. Still another instance is recorded of a hailstone having fallen in 1849 of nearly twenty feet in circumference. This hailstone is said to have fallen upon the estate of Mr. Moffat of Ord. We will only ask our readers to listen to one more hailstone story, in which it is related that during the reign of Tippoo, sultan, a hailstone fell as large as an elephant. Undoubtedly one of two things was true regarding this latter story; it was either a very large hailstone or a very small elephant. The historian fails to give the size of the elephant. There is no doubt, however, but that hailstones may adhere and form large masses owing to the violent agitation of the elements that always attends a hailstorm.

Hailstorms are almost universally attended by constant and heavy thunder and lightning, [Pg 126] together with violent winds. They usually occur on a very hot day, and when the air is filled to saturation with moisture. When this is the case a column of air is very highly heated at some point, when it ascends with great force into the upper regions of the atmosphere to a greater altitude than is common in the case of ordinary thunderstorms. Here it meets with an intensely cold body of air, when it is suddenly condensed and readily frozen as soon as condensed, which not only forms hailstones, but sets free the energy that has been carried up in the moisture globules. This results in frequent electrical discharges, causing great waves of condensed and rarefied air, which, in the rarefied portions, produces still more intense cold; so that we have the conditions for a mighty struggle between the elements, which is intensified by a constant and terrific electric cannonade. Undoubtedly there are also whirlwinds in the cloud, similar to those that sometimes visit the earth, which would tend to gather up the hailstones and aggregate them into large masses. It is a mighty battle between the moisture-laden, superheated air, ascending from the surface of the earth, and the powers residing in the upper regions of cold. Nature is constantly struggling to find an equilibrium of her forces, and a hailstorm is only one of the little domestic flurries that take place when she is setting her house to rights. Hailstorms are usually [Pg 127] confined to very narrow limits, and they can prevail on a grand scale only in hot climates, where we have the conditions for wide differences of temperature between the upper and lower regions of the atmosphere; and, also, where the conditions are favorable, for an enormous amount of absorption of moisture into the atmosphere.

When snow is formed in the atmosphere, the conditions are quite different from those of a hailstorm; it is usually in a lower plane of the atmosphere, and there is no violent commotion, as is the case with the latter. A volume of air laden with moisture comes in contact with a colder volume of air, when condensation takes place, as in the case of rain, except that the moisture is immediately frozen. In this case both volumes of air may be below the freezing point, but one is very much colder than the other. If the snow reaches the earth it will be because the air is below the freezing point all the way down. Snow is formed at all seasons of the year. We may have a snowstorm on a high mountain when we have extreme heat at sea-level.

In summer time of course the snow melts as soon as it falls into a stratum of air with a temperature above the freezing point, and continues its journey from that point as raindrops instead of snowflakes. In the formation of a snowflake Nature does some of her most beautiful [Pg 128] work. A snowflake first forms with six ice spangles, radiating from a common center. Shorter ones form on these six spokes, standing at an angle of about sixty degrees, on each side of each spoke, of such length and arrangement as to form a symmetrical figure or flower. They do not always take the same form, but follow the same laws that govern the formation of ice crystals. The structure of a snowflake may be often found upon a window pane of a frosty morning. Here, however, the free arrangement of the parts of a snow crystal are interfered with by its contact with the window pane, but while floating gently in the air there is the utmost freedom for the play of nature's forces as they apply to the work of crystallization.

The difference in structure of snowflakes is chiefly due to the conditions under which they are formed. If the moisture is frozen too rapidly the molecular forces that are active in crystallization do not have time to carry out the work, in its completeness of detail, as it will where the freezing process, as well as the condensing process, goes on more slowly.

CHAPTER XVI. [Pg 129]

METEORS.

Meteors are the tramps of interplanetary space. They sometimes try to steal a ride on the surface of the earth, but meet with certain destruction the moment they come within the aërial picket line of our world's defense against these wandering vagrants of the air. They have made many attempts to take this earth by storm, as it were, and many more will be made. They fire their missiles at us by the millions every year with a speed that is incredible, but thanks to the protecting influence of the great ocean of air that envelops our globe they become the victims of their own velocity.

Meteors or shooting stars are as old as the earth itself, and they are the material of which comets are made. Before it was determined what these meteors or shooting stars were, many theories were promulgated as to their origin. One was that they were masses of matter, large and small, projected by volcanic action from the face of the moon with such violence as to be brought within the attraction of the earth. Others supposed them to be the effect of certain phosphoric fluids [Pg 130] that emanated from the earth and took fire in the upper regions of the atmosphere. This, however, was mere speculation and without any scientific basis of fact. Anyone who has been an observer of shooting stars will have learned that there are certain periods of the year when they are more numerous than at other times; notably in August and November. Then again there are longer periods of many years apart. By persistent observation it has been established that there are great numbers of schools or collections of cosmic matter that fly through interplanetary space, having definite orbits like the planets. Any one of these collections may be scattered through millions of miles in length. A comet is simply one of these wandering collections of meteoric stones having a nucleus or center where the particles are so condensed as to give it a reflecting surface something like the planets or the moon. This enables us to see the outline of the comet to the point where the fragments of matter become so scattered that they are no longer able to reflect sufficient light to reach our eyes. The fringe of a comet, however, may extend thousands or even millions of miles beyond the borders of luminosity.

[Pg 131] There is scarcely a day or night in the year when more or less of these meteoric stones do not come within the region of our atmosphere, and when this happens the great velocity at which they travel is the means of their own destruction. They become intensely heated by friction against the atmosphere just as a bullet will when fired from a gun—only to a greater extent owing to the greater velocity. They disintegrate into dust which floats in the air for a time, when more or less of it is precipitated upon the surface of the earth. Disintegrated meteors, or star dust, as they are sometimes called, are often brought down by the rain or snow. Most of the shooting stars that we observe are very small, resembling fire-flies in the sky, but once in a while a very large one is seen moving across the face of the heavens, giving off brilliant scintillations that trail behind the meteor, making a luminous path that is visible for some seconds. These brilliant manifestations are due to one of two causes. Either there is a very large mass of incandescent matter or else they are so much nearer to us than in ordinary cases that they appear larger. It is more likely, however, that it is due to the former cause rather than the latter, from the fact of its apparently slow movement as compared with the smaller shooting stars. It has been determined by observation that the average meteor becomes visible at a point less than 100 miles above the earth's surface. It was found as far back as 1823 that out of 100 shooting stars [Pg 132] twenty-two of them had an elevation of over twenty-four and less than forty miles; thirty-five, between forty and fifty miles; and thirteen between seventy and eighty miles. It was determined by Professor Herschel that out of sixty observations of shooting stars the average height of their first appearance was seventy-eight miles and their disappearance was at a point fifty-three miles above the earth.

It is a matter of history, however, that sometimes these meteoric stones descend to the surface of the earth before they are entirely disintegrated. A fine specimen of this kind is to be seen in the Smithsonian Institution. There are over forty specimens of these aërolites (air-stones) in the British Museum, labeled with the times and places of their fall. Instances of falling to the earth are so rare that there is little to fear from these wandering missiles of the air. We do not remember a case where life or property has suffered from the fall of a meteor.

This brings us to the consideration of the part which the great air envelope surrounding the earth plays as a protection against many outside influences. For instance, if it were not for the air, millions of these meteoric stones would be showered upon our earth every year and at certain times every day, which would render the earth untenable for human existence. We should be at [Pg 133] the mercy of those wandering comets whose fringes strike our atmosphere more or less deeply at frequent intervals. It is not impossible that the earth may at some time pass directly through one, and yet there is little danger that in such a case there would be more than an unusual display of celestial fireworks.

From the facts that have been above stated it will be apparent to anyone that the number of these meteoric stones in the air is being constantly reduced by their constant collision with the atmosphere and consequent reduction to ashes or dust. Another conclusion is that the earth must be gradually, but imperceptibly perhaps, increasing in size on account of the constant settling upon its surface of meteoric dust.

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CHAPTER XVII.

THE SKY AND ITS COLOR.

In the chapters on light in Vol. II. it will be stated that we see all objects by a reflected light, except those that are self-luminous, such as the sun or any other source of light. We see the moon and many of the planets entirely by reflection. There are myriads of smaller objects, too small to be seen as such, even under a microscope, that still have a power to reflect light that is sensible to our vision. The air surrounding the globe is literally filled with these microscopic light reflectors. They serve to give us a diffused light which enables us to see clearly all visible objects. We have all noticed the effect of a single electric arc light, situated at a distance from any other source of light, and how it casts extremely dark shadows and very high lights; so much so that it is difficult to see an object perfectly in this light, because the part of an object that is under the direct rays of the lamp is so highly illuminated that the shadow, by comparison, has the effect of [Pg 135] simply a dark blot without form or shape. Many of you have noticed in a country village, where the streets are lighted with electric arc lamps, what a difference there is in the illuminating effect between a clear and a foggy night. When there is a fog, or when the clouds hang low down, we get a reflection from these which tends to diffuse and soften the powerful light rays that are sent out by these lamps. This effect is especially noticeable when the night is only moderately foggy. Each globule of moisture floating in the air becomes a reflector of light, and by myriads of reflections and counter reflections the light (which on a clear night is concentrated) is diffused over a large area, producing an illumination which for practical purposes is far superior to that produced on a clear night. When the latter condition prevails the rays of light are so intense on objects immediately surrounding the lamps that one is blinded; so that the places which are in shadow seem darker than they would be if there were no light at all. The only way to prevent this effect is to have the lights so close together that there will be cross lights, which tend to break up the intensity of the shadows. This principle of light diffusion is taken advantage of to produce an even illumination in stores that are lighted only on one or two sides. This is effected by a series of prisms or reflecting surfaces that are cast upon the panes of glass. [Pg 136]

If now there were no atmosphere—or, to state it differently—if there were no floating substances in the atmosphere, the sun would produce an effect upon the earth similar to that of a single electric light. The lights would be extremely high, and the shadows extremely dense. To one looking off into space, the sky, instead of having the blue appearance that we see, would have the effect of looking into a deep, dark abyss without illumination.

Tyndall has shown us by a beautiful experiment that if there be in a glass tube a mixture of gases related to each other in a certain way chemically, they will combine into small globules or particles similar to moisture in the air. If now a beam of light is thrown upon this tube and a dark screen put behind it, we shall, in the beginning of the experiment, simply see the dark screen. As soon, however, as the molecules of the gases have combined in sufficient numbers to produce particles of sensible size we begin to have a reflection of light from them, the color of which is constantly changing as the combining particles grow in size. At a certain stage in its progress the color which the mixture of gases assumes is a beautiful azure blue, rivaling in purity the finest skies of Greece or southern Italy. [Pg 137]

The sun is the great lamp that illuminates the world, while the atmosphere, which is filled with particles of various substances, becomes the shade of the lamp which diffuses and softens the light and gives it its color tones, whether of warmth or coldness. We could not well do without the reflected light of the sky. The poetry of life would be sadly marred. The beautiful effects of color and purity of tone would be wanting. We need to bathe in light as much as in water, and the character of the light is almost as important as the character of the water. Imagine a world with an atmosphere devoid of all substances that would in any way reflect light or give to it softness or color tone. Imagine a sun or a moon without visible rays—for without a reflecting atmosphere there would be none. Imagine a sky that was no sky at all, but only a dark void, with no protecting vault. Think of the shadows, so dark that you could see nothing in them. These would be some of the effects that would come from an atmosphere that had no sky substance in it. Imagine the world lighted by one great arc light. The reflex action upon the race living in such a light would be anything but desirable. The world would develop into an arc-light civilization—if one can imagine what that would be like; certainly one of intensely violent contrasts. Look on this picture and let us be thankful for the blue sky and golden sunsets. [Pg 138]

"But," you ask, "why is the sky blue?"

In one of the chapters on the subject of light in Vol. II. the properties of soap bubbles are discussed. It is shown that when a film is stretched across the mouth of a tumbler held in a position so that the film is perpendicular, by the action of gravity (the moisture constantly falling to the lower part of the film) it will continually grow thinner, and horizontal bands of color will appear upon it,—first red, then followed by the other colors of the solar spectrum, ending with violet.

It is also stated that every color of light has a definite wave length. Where a band of blue color appears upon the film we know that its thickness is right for the wave length of that particular color which is reflected from the back of the film to the eye. If we could conceive the blue vault of the heavens to be half a sphere of a soap bubble, the color that the sky would appear to us (if the light could be thrown upon it from beneath) would be determined by the thickness of this film. If the film was 1-156,000 of an inch the sky would be red instead of blue. To reflect the other colors the film would have to grow thinner for each color, in the progression from red to violet. The color of the sky is determined by a light-reflection from minute globules of moisture floating in [Pg 139] the air. If the sky is blue, then the globules must be of the right diameter to reflect that color. The various tints and colorings of the sky are determined by what is found in the atmosphere, and this is the reason why skies differ in coloring and tone in different sections of the globe. The finest skies are probably found in semi-tropical regions like southern Italy, Greece, and California.

In 1892 I visited Greece in the early part of June. In crossing the Adriatic, from Brindisi to Patras in Greece, the route was through the Ionian Islands that are grouped along the southwestern shore of Albania. The sky was without a cloud, and its beautiful blue color was reflected in the waters of the Adriatic, and I never shall forget the impression made upon my senses when we first came in sight of the mountains on the west coast of Albania. At this point they rise abruptly from the water and are colored with that peculiar azure haze, mixed with a shading of warmth, which is an effect that distance gives in the classic atmosphere of old Greece. The effect upon the beholder is to intoxicate the senses and to fill him with that deliciously poetic feeling that always comes when standing in the presence of the sublime in nature. It was not the mountains themselves that produced the effect, for I had seen grander than these; but it was the sky on the [Pg 140] mountains. When we look at a distant mountain it seems to be partly hidden by a peculiar haze that is the color of the sky at that time; we are really looking at the mountain through a portion of the sky. While in Athens I took a trip to the top of Mount Pentelicus, which separates the plains of Athens on the south from those of Marathon on the north. From the summit of this mountain we have a most wonderful view of the archipelago of the Ægean Sea—a beautiful map of blue water and brown islands that melt together in the distance. At our feet lay the historic plains of Marathon, and in the distance rose the snow-capped peaks of Mount Olympus. It is doubtful if the world furnishes a more beautiful combination of ocean, island, continent, and sky than can be seen from Mount Pentelicus. Myriads of brown islands set in the bluest of water—graceful in outline and multiform in shape—jutting headlands and land-locked harbors—strong in color and outline in the immediate foreground, but gradually melting together in the distance, the brown becoming bluer and the blue a softer blue till the whole is lost on the horizon in a sky that shades back to the zenith in an ever-changing azure that for purity of tone baffles all description.

What wonder that a people born under such skies and whose eyes have feasted on such beauties [Pg 141] in nature should conceive and execute such a masterful work of art as the Parthenon! While the variation of landscape, the stretch of water filled with islands, and the mountains capped with eternal snow were a prominent part of the picture, it was the sky with its beautiful color-tones that after all gave it its wonderful charm.

The skies in a northern latitude are colder and grayer, due to the fact that nearly always there is a certain degree of condensation of moisture existing, which, while it does not take the form of a cloud, still gives a toning to the sky.

There is no doubt but that the color-tones of the sky have an influence upon the character and temperament of the people who live under them. Under semi-tropical skies the poetic nature is more strongly appealed to, and a man is more likely to be controlled by his dreamy imaginings than his cold calculations. We find this latter characteristic prevailing to a greater or less extent among the people who live under colder and sterner skies. If all these qualities or influences could be combined in the right way, the race would be stronger intellectually and in other ways. It is always dangerous to a race of people to be developed along certain lines only. The development should be symmetrical. The strongest men are not those who are simply coldly [Pg 142] intellectual, neither those who are simply emotional and sentimental, but those in whom heart, mind, and soul are so related that each one of these elements re-enforces and strengthens the others.

At certain seasons of the year and in certain localities it is not uncommon to have wonderfully beautiful displays of coloring upon the skies and clouds at sunset. The question is often asked why we do not see these displays at other times in the day than at sunrise and at sunset—for the same effects are seen in the morning, but they are not noticed so often, because to do so would interfere with the habits of the average man and woman.

The reason for this change of coloring is the angle at which the sun's rays strike the clouds of an evening sky, which are reflected to our eyes. When the sun is high in the heavens it shines against the back of the clouds, from the point of view of a person standing on the surface of the earth. It also shines a shorter distance through the air at midday than at sunset. At sunset the rays are able to shine on the under side of a cloud, especially if it is high in the air. The moisture globules of which the cloud is made up are much larger than the transparent ones that are uncondensed and just as they were when released in the process of evaporation.

As we have already seen, the reflections from these minute globules give us the blue coloring of [Pg 143] the sky and are very much smaller in diameter than a globule that is able to reflect the red ray. When these small globules are condensed into cloud a great number are combined into one globule, and they are of all sizes, from the globule of evaporation to that of the raindrop when precipitation takes place. We have, then, in the various stages of cloud formation all conditions present for reflecting the various colors and combinations of colors that are found in the solar spectrum. Hence it is that, under certain conditions of atmosphere and cloud formation, we see at sunset painted upon the sky those wonderful combinations of colors, more beautiful and delicate in shading, more various in combination and purer of tone, than any artist, however cunning his fingers or brilliant his pigments, has ever been able to truthfully reproduce. Even when the sky is cloudless it often assumes a brilliant hue, which is partly a reflection from invisible moisture globules and partly due to floating particles of dust that may have been driven up from the surface of the earth, or may be the ashes of meteorites disintegrated by contact with the air.

Some years ago, commencing in August, 1883, there was a wonderful exhibition of red skies at sunset that lasted for several hours after twilight ordinarily disappears. This phenomenon ran [Pg 144] through a period of several weeks, gradually fading away. It was afterward determined that these displays were occasioned by small particles of ashes or dust floating high in the air, that were thrown off from the volcanic eruption of Krakatoa in the Island of Java. By the general circulation of the air the ashes were carried to all parts of the world, making a circuit of the earth in from twelve to thirteen days—which showed a velocity of over eighty miles an hour. This is an instance of the high velocity of the air currents in the upper regions of the atmosphere. The reason why the illumination extended so late in the night was because of the great height that these particles of dust attained. The higher the reflecting surfaces are in the air the longer they may be seen after sunset. Ordinary twilight is caused by a reflection of sunlight from the upper air; and from its duration as ordinarily observed it is estimated that the reflection does not proceed from a point more than thirty-six miles high. In the higher latitudes the twilight is long, from the fact that the sun does not go directly down, and if we go far enough north the whole night is twilight. In the tropical regions the twilight is shorter than at any other point on the globe for reasons that are obvious. The sun there goes directly down and is soon hidden behind the earth. [Pg 145]

There are other optical effects to be seen sometimes on the horizon somewhat resembling twilight. The "aurora borealis" (northern lights), which we describe in Vol. III., is seen in the northern skies at certain times, and has very much the appearance of twilight in some of its phases. It is constantly changing, however, and is easily distinguished by anyone who has observed both. These appearances are undoubtedly electrical. There is another phenomenon seen in the arctic regions that causes a band of white light to appear on the horizon called "ice blink," and it is caused by the reflections from the great icebergs that abound in that region.

Curious optical effects are sometimes observed a little after sunset in the form of streamers or bands of light that shoot up into the sky, sometimes to a great height. These are undoubtedly due to cloud obstructions that partially shut off the sun's rays from a part of the sky, but allow it to shine with greater brilliancy in the path of these bands of light.

It will be seen from the foregoing that the sky in all of its phases is a product of sunlight and the substances that float in the air, including moisture, not only in the invisible state, but in all the stages of condensation, as well as particles of floating dust.

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CHAPTER XVIII.

LIQUID AIR.

Air, like water, assumes the liquid form at a certain temperature. Water boils and vaporizes at 212 degrees Fahrenheit above zero, while liquid air boils and vaporizes at 312 degrees below zero.

Heat and cold are practically relative terms, although scientists talk about an "absolute zero" (the point of no heat), and Professor Dewar fixes this point at 461 degrees Fahrenheit below zero. Others have estimated that the force of the moon during its long night of half a month, is reduced in temperature to six or seven hundred degrees below, which is far lower than Professor Dewar's absolute zero. However this may be, to an animal that is designed to live in a temperature of 70 or 80 degrees Fahrenheit, any temperature below zero would seem very cold. If, however, we were adapted to a climate where the normal temperature was 312 degrees Fahrenheit below zero, we should be severely burned if we should sit down upon a cake of ice. Such a climate [Pg 147] would be impossible for animal existence, for the reason that there would be no air to breathe, since it would all liquefy.

Liquid air is not a natural product. There is no place on our earth cold enough to produce it. If the moon had an atmosphere (which it probably has not) it would liquefy during the long lunar night, for heat radiates very rapidly from a planet when the sun's rays are withdrawn from it.

As you have already surmised, liquid air is a product of intense cold. Any method that will reduce the temperature of the air to 312 degrees Fahrenheit below zero will liquefy it. Great pressure will not do this, for we may compress air in a strong vessel until the pressure on every square inch of the vessel is 12,000 pounds, or six tons, and still it will not liquefy unless the temperature is brought down to the required degree of coldness. If this is done it will change from a gas to a liquid, but will occupy as much space as before, if it is condensed to a pressure of six tons to the square inch.

Until twenty years ago it was supposed that oxygen and atmospheric air (the latter a mixture of oxygen and nitrogen) were fixed gases and could not be liquefied. In 1877, it is said that Raoul Pictet obtained the first liquid oxygen, but only a few drops. About fifteen years later Professor Dewar of the Royal Institution, London, succeeded in liquefying not only oxygen but atmospheric [Pg 148] air. And besides liquefying the air he made ice of it.

In 1892 I visited London, where I met Professor Dewar, who invited me to witness an exhibition of the manufacture of liquid oxygen—and incidentally liquid air—at the Royal Institution. To me it was a most wonderfully interesting event. I saw air, taken from the room, gradually liquefy in a small glass test tube open at the top. When the tube was withdrawn from the refrigerating chamber it boiled by the heat of the room, and rapidly evaporated. We lighted a splinter of wood and blew it out, leaving a live spark on the end of it, and held it over the mouth of the tube, knowing that if anything like pure oxygen were evaporating the splinter would relight and blaze (an old experiment with oxygen gas). At first the splinter would not relight, because the evaporating gases were a mixture of oxygen and nitrogen in the proportions to form air. But owing to the fact that nitrogen evaporates sooner than oxygen, a second trial was successful, for the splinter immediately began to blaze, showing that the gas evaporating then was pure, or nearly pure, oxygen.

When the liquid oxygen was poured into a saucer and brought into proximity with the poles of a powerful magnet the liquid immediately rushed out of the saucer and clung to the magnet poles; [Pg 149] showing that oxygen is magnetic.

Since that time other experimenters have succeeded in making liquid air on a comparatively large scale, and the process is simple when we consider some of the old methods.

Mr. Tripler of New York, who has made liquid air in great quantities, does it substantially as follows: First, he compresses air to about 2500 pounds to the square inch. Of course the air is very hot when it is first compressed because all the air in the tank has been reduced in bulk about 166 times, and all the heat that was in the whole bulk of air is concentrated into one-166th of the space it occupied before it was compressed. It is 166 times hotter. There are two sets of pipes running from the compressor to a long upright tank called the liquefier. These pipes pass through running water, so that the compressed air is quickly cooled down to the temperature of the water (about 50 degrees Fahrenheit). The pipes—at least one set of them—run the whole length of the liquefier, and most likely are coiled. This set of pipes contains the air to be liquefied. A second set of pipes runs to the bottom of the liquefier, where there is a valve. By opening this valve a jet of compressed air is allowed to play on the other set of pipes, when intense cold is produced by the sudden expansion of the air. This cold air rushes up around the pipe containing [Pg 150] the air to be liquefied and escapes at the top, thus absorbing the heat until the temperature is reduced to 312 degrees below zero. Then the air liquefies and runs into a receptacle, where it may be drawn off at pleasure.

It will be seen that a large part of the compressed air is wasted in cooling the remainder sufficiently to liquefy.

The use to which liquid air may be put, advantageously, is an unsolved problem; but no doubt it will have a place in time. All great discoveries do. Electricity had to wait a long time for recognition; but what a part it plays now in the everyday life of the whole civilized world!

Curious effects are produced by this intense cold. Meat may be frozen so hard that it will give off a musical tone when struck. Here is a pointer for the seeker of novelties in the line of musical instruments.

Liquid air furnishes a beautiful illustration of the fact that a burning gas jet is continually forming water as well as giving out heat and light. If we put liquid air into a tea kettle and hold it over a gas jet, ice will form on the bottom from the water created by the flame, and it will freeze so hard that the flame will make no impression upon it, other than to make the ice cake grow larger. [Pg 151]

Although liquid air is not found in nature, and is therefore called an artificial product, it is produced by taking advantage of natural law. Without the intellect of man it never would have been seen upon this earth; and the same may be said concerning many things in our world, both animate and inanimate. The genius of man is God-like. He lifts the veil that shrouds the mysteries of nature, and here he comes in very touch with the mind of the Infinite. Man interprets this thought through the medium of natural law, and lo, a new product!

How much life would have been robbed of its charm and interest if all these things had been worked out for us from the beginning! For there is no interest so absorbing and no pleasure so keen as that of pursuit when the pursuer is reaching out after the hidden things that are locked up in Nature's great storehouse. From time to time she yields up her secrets, little by little, to encourage those who love her and are willing to work, not only for the pleasure of the getting, but for the highest and best good of their fellows.

WATER. [Pg 152]

CHAPTER XIX.

RIVERS AND FLOODS.

Water covers such a large proportion of the earth's surface and is such an important factor in the economy of nature that it becomes a matter of interest to study the process of its distribution. Water is to our globe what blood is to our bodies. A constant circulation must be kept up or all animal and vegetable life would suffer. Here, as in every other operation of nature, the sun is the great heart and motive power that is active in the distribution of moisture over the face of the globe.

The total annual rainfall on the whole surface of the earth amounts to about 28,000 cubic miles of water. Only about one-fourth of this amount ever reaches the ocean, but it is either absorbed for a time by animal and vegetable life or lifted through the process of evaporation into the air as invisible moisture, when it is carried over the region of rainfall and there condensed into water and falls back upon the earth—only to go through the same operation again. The whole surface of [Pg 153] the earth is divided into drainage areas that lead either directly through rivulets and rivers to the ocean, or into some land-locked basin, where it either finds an outlet under ground or is kept within bounds through the process of evaporation, the same as is the case with our great oceans. In North America the amount of drainage area that has no outlet to the ocean amounts to about 3 per cent. of the whole surface. In other countries the percentage of inland drainage is much larger. The great Salt Lake in Utah is an instance where there is no outlet for the water except through the medium of evaporation. Inasmuch as all rivers and streams contain a certain proportion of salt,—especially in such strongly alkaline land regions as the Great Basin of the North American continent,—these inland lakes in time become saturated with this and other mineral substances.

Salt is constantly being carried into the lake by the water of the stream that feeds it, and the water is continually being evaporated, leaving the salt behind. This process has been going on in the valley of Utah for so long a period that 17 per cent. of the contents of the lake is salt. The Humboldt River in Nevada, which empties into a small lake of the same name, and lies at the foot of the Humboldt Mountains, is said to have an underground outlet. This must be the case, [Pg 154] because the area of the lake is very small as compared with Salt Lake, while the river that feeds the latter is very small compared with the one that flows into the former. That is to say, in the one case a very small stream empties into a large lake, while in the other case a much larger stream feeds a very small lake. Besides, Humboldt Lake, unlike the Great Salt Lake, is said to be a fresh-water lake; if it had no outlet it would become in time saturated with salt. The largest body of water in the world having no outlet to the ocean is the Caspian Sea, on the border between Asia and Russia in Europe, it being 180,000 square miles in extent.

Where rivers empty into large bodies of water, such as the great chain of lakes on the northern border of the United States (and these lakes have an outlet connecting one with the other, and finally by a river to the ocean) a constant circulation is being kept up, and the water remains fresh. Owing to the fact, however, of the great evaporating surface that these lakes afford, there is a greater disproportion between the rainfall upon the drainage area tributary to these lakes, and the amount of discharge through the St. Lawrence River, than would be the case with a river that was not connected with a system of lakes. The amount of rainfall upon the area drained by [Pg 155] the Mississippi River during one year amounts to about 614 cubic miles of water, while the discharge at the mouth of the Mississippi River is only about 154 cubic miles. The difference between the two figures has been carried up by the process of evaporation or stored in vegetation. These figures vary considerably, however, with different years.

The proportion of rainfall to discharge will vary greatly in different rivers from other causes than having a large evaporating surface. This variation is due to the difference in the ability of the soil to retain water after a rainfall. In some drainage areas the ground is more or less impermeable to water, and in this case the water runs readily off, causing a sudden rise in the river; and as suddenly it reaches the low-water mark. In other drainage areas the ground is very permeable to water, so that the rain penetrates to a greater depth into the earth, where it is held, and by a slow process drains into the rivers, while much more of it is carried off by evaporation and into vegetation than is the case in the drainage district before mentioned.

The courses of rivers are determined by the topography of the country through which they flow. The sinuous windings, that are found to be a characteristic of nearly all rivers, are caused by the [Pg 156] water, through the force of gravity, seeking the lowest level, and avoiding obstructions, which they can flow around more easily than remove.

Great rivers often change their courses, especially where they flow through a region of made earth, such as is the case with the lower Mississippi River, and in other great rivers of the world. The loose earth is continually shifted by the current, and where the current is not very strong it will often hold the water back to such an extent of accumulated weight that the flood will break over at some weak point on its banks and make a new course for itself.

One of the great rivers of China—the Hwangho—often causes dire destruction to life and property owing to change in its bed from time to time. It is estimated that between the years of 1851-66 this river caused the loss of from 30,000,000 to 40,000,000 lives through drowning and famine by the destruction of crops.

Floods in rivers are occasioned from various causes. Of course the primary cause is the same in all cases, that is, from precipitation of moisture in the form of rain or snow. Some rivers are so related to the area of rainfall and to the permeability of the soil that there is but little variation in the amount of discharge throughout the year. The great river of South America, the Amazon, is [Pg 157] an instance of a river of this class. A certain number of the smaller rivers that feed it lie in the area of rainfall during the whole of the year; for instance, the streams of the upper Amazon are being fed by rains at one season of the year, when those feeding the river lower down are at the lowest stage. When the rainy season prevails in the upper section of the river the dry season prevails farther down, while at another season of the year these conditions are reversed. Therefore, though the Amazon has a larger drainage basin than any other river in the world, and in some parts the yearly rainfall is 280 inches, there is no very great fluctuation in the stages of water. The Orinoco River, which flows through Venezuela, and whose drainage area is largely covered with mountains, has a greater fluctuation than any other river, the difference between high and low water amounting to seventy feet.

The River Nile has an annual rise of from fourteen to twenty-six feet. This river is the sole dependence of the inhabitants of lower Egypt, and their sustenance depends upon the height to which the river rises; if it does not rise high enough the agricultural lands are not sufficiently irrigated, and if it rises too high their crops are destroyed by the floods. In this section they depend entirely upon the overflow of the Nile for irrigation, and not upon the rainfall. There is [Pg 158] scarcely ever a rainfall in lower Egypt except about once a year on the coast of the Mediterranean. After ascending the river for a short distance we come into an area of no rain for a distance of 1500 miles along the river. Egypt has a superficial area of about 115,200 square miles, and only about one-twelfth of this area is in a position to be cultivated.

As there is no rainfall in this region, the sole dependence for agricultural purposes is from the River Nile when it rises to a sufficient height to admit of irrigation. The river brings down quantities of rich earth which during the overflow is deposited, and thus the agricultural regions are refertilized annually.

The River Nile is what is called a tropical river and is fed by the rains in upper Egypt caused by the monsoon winds that prevail in that section of Africa during the summer season, as they do in India. As has been explained in a former chapter, the monsoon winds blow steadily for about six months from off the southern ocean. These winds are highly charged with moisture, which is not precipitated till it strikes the mountainous regions of the interior. Here the high mountains, which are often snow-capped, cause a profuse precipitation, which runs off into the various feeders of the Nile, causing a gradual rise in the river that reaches the highest point about [Pg 159] September of each year. If the Nile should dry up, or if the annual floods should materially change in height, it would make a desert region of all that portion of Egypt now so productive.

The great rivers of China, the Yang-tse-Kiang and the Hwangho, are also tropical rivers and have an annual flood. Sometimes the rise is as much as fifty-six feet. These annual floods are also caused by the monsoon winds that carry moisture from the ocean, which is condensed and precipitated in the mountains of central Asia. The conditions are substantially the same as those which prevail at the sources of the Nile in Africa.

Rivers are produced from all sorts of causes, some of them flowing only during the rainy season, while others are fed by melting snow from the higher mountains, and as the snow is rarely melted away entirely during the summer, in the high mountains, there is a continual flow from this source. The snow forms a system of storage, so that the water is held back and is gradually given up as it melts. If this were not true mountainous regions would be subjected to disastrous floods. If the precipitation were always in the form of rain it would immediately run off instead of being distributed over a whole season. The Platte is an instance of a river largely fed by the melting snows—of the Rocky Mountains. [Pg 160]

In the region of glaciers in the mountains of Alaska and Switzerland rivers are fed by the melting ice. These rivers are usually of a milky color occasioned by the pulverization of rock caused by the grinding of the great glaciers as they flow down the gulches in the mountain side. In some regions these glacial rivers have a diurnal variation. This is caused by the fact that the glacier is so situated that it freezes at night, which checks the flow, and thaws in the daytime, which increases it.

Rivers are to the globe what the veins are to the animal organization. They pick up the surplus moisture not needed in the growth of vegetation and for the sustenance of animal life, and carry it on, together with the débris that it gathers in its course, to the great reservoirs, the seas and oceans, where it is redistilled and purified by the action of the sun's rays. From here it is carried back in the form of invisible moisture and again precipitated in the purified state, to help carry on the great operations of growth—animal and vegetable. The vaporized moisture that is carried back by the winds and redistributed corresponds to the blood, after it has been purified and is carried back through the arteries to the extremities and capillary vessels which feed and nourish the bodily organs.

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CHAPTER XX.

TIDES.

Anyone who has spent a summer at the seashore has observed that the water level of the ocean changes twice in about twenty-four hours, or perhaps it would be a better statement to say that it is continually changing and that twice in twenty-four hours there is a point when it reaches its highest level and another when it reaches its lowest. It swings back and forth like a pendulum, making a complete oscillation once in twelve hours. When we come to study this phenomenon closely we find that it varies each day, and that for a certain period of time the water will reach a higher level each succeeding day until it culminates in a maximum height, when it begins to gradually diminish from day to day until it has reached a minimum. Here it turns and goes over the same round again. It will be further observed that the time occupied between one high tide and the next one is a trifle over twelve hours. That is to say, the two ebbs and flows that occur each day require a little more than twenty-four hours, so that the tidal day is a little longer than [Pg 162] the solar day. It corresponds to what we call the lunar day.

As all know, the moon goes through all its phases once in twenty-eight days. The tide considered in its simplest aspect is a struggle on the part of the water to follow the moon. There is a mutual attraction of gravitation between the earth and the moon. Because the water of the earth is mobile it tends to pile up at a point nearest the moon. But the earth as a whole also moves toward the moon, and more than the water does, keeping its round shape, while its movable water (practically enveloping it) is piled up before it toward the moon and left accumulated behind it away from the moon. So that in a rough way it is a solid sound earth, surrounded by an oval body of water: the long axis of the oval representing the high tides, which, as they follow the moon, slide completely around the earth once in every twenty-four hours. Thus, there are really two high tides and two low tides moving around the earth at the same time; and this accounts for the two daily tides.

We have accounted for the time when they occur in the fact that the water attempts to follow the moon, but this does not account for the gradual changes in the amount of fluctuation from day to day. The problem is complicated by the fact that the sun also has an attraction for the earth as [Pg 163] well as the moon. But from the fact that the sun is something like 400 times further from the earth than the moon is, and also the fact that the attraction of one body for another varies inversely as the square of the distance, the moon has an immense advantage over the sun, although so much smaller. If the power of the moon were entirely suspended, or if the moon were blotted out of existence, there would still be a tide. The fluctuation between high and low tide would not be nearly so great as it is at present, but it would occur at the same time each day, because it would be wholly a product of the sun.

It will be easily seen that these two forces acting upon the water at the same time will cause a complicated condition in the movement of the waters of the ocean. There will come a time once in twenty-eight days when the sun and the moon will act conjointly, and both will pull in the same direction at the same time upon the water. This joint action of the sun and moon produces the highest tide, which is called the "spring" tide. From this point, however, the tides will grow less each day, because the relation of the sun and moon is constantly changing, owing to the fact that it requires 365 days for the sun to complete his apparent revolution around the earth, while the [Pg 164] moon does her actual course in twenty-eight days. When the sun and moon have changed their relative positions so that they are at right angles to each other with reference to the earth—at a quarter-circle apart—the sun and moon will be pulling against each other; at least this is the point where the moon is at the greatest disadvantage with reference to its ability to attract the water.

Because one-quarter around the earth the sun is creating his own tide, which to that extent counteracts the effect produced by the moon, the tide under the moon at this point is at its lowest point and is called the "neap" tide. When the moon has passed on around the earth to a point where it is opposite to that of the sun—at a half-circle apart—there will be another spring tide, and then another neap tide when it is on the last quarter, and from that point the tide will increase daily until it reaches the point where the sun and moon are in exact line with reference to the earth's center, when another spring tide occurs. From this it will be seen that there are two spring tides and two neap tides in each twenty-eight days. This is the fundamental law governing tides.

There are many other conditions that modify tidal effects. Neither the sun nor the moon is always at the same distance from the earth. So that there will be a variation at times in high and low [Pg 165] tides. For instance, it will happen sometimes that when both the sun and moon are acting conjointly they will both be at their nearest point to the earth, and when this is the case the spring tide will be much higher than usual.

For many years the writer has observed that artesian wells, made by deep borings of small diameter into the earth to a water supply, have a daily period of ebb and flow, as well as a neap and spring tide, the same as the tides of the ocean, except that the process is reversed. The time of greatest flow of an artesian well will occur at low tide in the ocean. This might be accounted for from the fact that when the tide is at its height the moon is also pulling upon the crust of the earth, which would tend to take the pressure off the sand rock which lies one or two thousand feet below the surface and through which the flow of water comes, and thus slacken the flow. When the moon is in position for low tide, the crust of the earth would settle back and thus produce a greater pressure upon the water-bearing rock. This is the only theory that has suggested itself to the writer that would seem to account for these phenomena.

Looked at from one standpoint, it is easy to account for tidal action. But when we attempt to make up a table giving the hour and minute as well as the height of the tide at that particular [Pg 166] time we find that we have a very complicated mathematical problem. However, tables are made out so that we know at just what time in the day a tide will occur every day in the year.

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CHAPTER XXI.

WHAT IS A SPONGE?

Before entering upon the great subject of water and ice—two of the most tremendous factors in world-building—let us consider a small matter, so far as its permanent effects are concerned, yet one which enters largely into the comfort and health of mankind, and which, though an animal, may be discussed where it belongs—under "Water."

There are few things more familiar about the ordinary household than a piece of sponge, and yet, perhaps, there are but few things about which there is so little known. The sponge had been in use many, many years before it was given a place in either the animal or vegetable kingdom. The casual observer, because he saw it attached to a rock, jumped to the conclusion that it was of vegetable origin. But after being kicked back and forth, so to speak, from one kingdom to the other, even by what are called well-educated people, it has finally been received into the family of animals; a dignity in which the sponge itself seems to take but little interest. [Pg 168]

The sponge is found in the bottom of the sea; at no very great depth, however. It is usually attached to a rock or some other substance and it is due to this fact chiefly that it has been classed as a vegetable. At least one scientist has attempted to give it a place between the two kingdoms, but this only adds confusion without giving any satisfactory explanation of its origin. It seems to belong to a very low order of animal life. It breathes water instead of air, but probably, like many other water animals, it absorbs the oxygen from the air which is more or less contained in the water. There is a process of oxidation going on within the sponge in a manner somewhat as we find it in ordinary animal life, and like the animal it expels carbon dioxide. All this, however, is carried on apparently without any lungs or any digestive organs, or in fact any of the organs that are common to the animals of the higher order. The sponge, however, as we see it in our bathrooms, is only the framework, bony structure, or skeleton of the animal.

The sponge is exceedingly porous and readily absorbs water or any fluid by the well-known process of capillary attraction. The sponge fiber is very tough and is not like anything known to exist in the vegetable kingdom. The substance analyzes almost the same as ordinary silk, which all know is an animal product. If we burn a piece of sponge it exhibits very much the same [Pg 169] phenomena as the burning of hair or wool, and the smell is very much the same.

The structure of a piece of sponge when examined under a microscope is a wonderfully complicated fabric. Under the microscope it shows a network of interlacing filaments running in every direction in a system of curved lines intersecting and interlacing with each other in a manner to leave capillary openings.

It is a wonderful structure, and one that a mechanical engineer could get many valuable lessons from. It will stand a strain in one direction as well as another. There are no special laminations or lines of cleavage; it is very resilient or elastic, and readily yields to pressure, but as readily comes back to its normal position when the pressure is relieved. If we examine the body of a sponge we shall notice that there are occasional large openings into it, but everywhere surrounded by smaller ones. If we should capture a live sponge and place it in an aquarium with sea water, where we could study it, we should find a circulation constantly going on, and that water was constantly sucked in at the smaller openings all over the outside of the sponge and as continuously ejected from the large openings. This process constitutes what corresponds in the higher order of animals to both respiration and blood circulation, combined. The sponge feeds [Pg 170] upon substances that are gathered up from the sea water, and breathes the air contained in the same, so that it breathes, eats, and drinks through the same set of organs.

When we first capture a live sponge from the sea it has a slimy, dirty appearance, and is very heavy. The sponge is found to be filled with a glutinous substance that is the fleshy part of the animal. It is very soft and jelly-like, and after the sponge is dead it is readily squeezed out, by a process which is called "taking the milk out," which leaves simply the skeleton, the only useful part as an article of commerce. This fleshy substance, in life, has somewhat the appearance and composition of the white of an egg.

The mechanical process by which the sponge takes its nourishment is exceedingly interesting. There are small globe-shaped cells with openings through them that are lined with little hairlike projections that move in such a manner as to suck the water in at one side of the cell and push it out at the other. These little fibers are technically called "cilia." We might describe them as little suction pumps that are located at many points in the sponge, all acting conjointly to produce a circulation through the finer openings or capillary vessels and finally discharging into the larger chambers which carry off the residue. If we should analyze the water as it is sucked into the [Pg 171] sponge and that which issues from it through the larger openings, we should find a difference between the two. The expelled water would contain more or less carbon dioxide.

There are many different varieties of sponge, and, while they all possess certain characteristics in common, they are still very different in many respects. Some of them are large and coarse, while others are exceedingly soft and velvety. What is called a single sponge is a colony of animals rather than a single animal; at least they are so regarded by zoölogists. This can hardly be true if we regard the sponge itself as a part of the animal. If the sponge is simply regarded as the house in which the animal lives then it becomes a great tenement with numerous occupants. But it is a tenement upon which the life of the sponge depends, and is a part of it.

The sponge could not breathe without the fibrous structure in the cells containing the machinery for producing the circulation. It will be seen that the sponge, while it is an animal, is of the very simplest variety, so far as its organs are concerned. True, its framework is very complicated, but the organs for sustaining the life of the animal are the simplest possible. The little self-acting pumps pull the water into the sponge through the smaller openings, where it appropriates the [Pg 172] food substance from the water and where a chemical action takes place which builds up the fleshy substance of the animal, and then expels the residue which is not needed to support its life.

Simple as it is, however, as a mechanical structure, the life and growth of the sponge is as mysterious as that of the most highly organized animal or even the soul of man. We can study out the structure of a plant or animal; we can analyze it and tell what are the elements of which it is composed; we can describe the mechanical operations that are carried on and the chemical combinations that take place, but no man has ever yet solved the mystery of life, even in the lowest form—whether animal or vegetable.

The sponge, whether considered as a single or compound animal, has the power to reproduce itself, and here the mystery of life is as much hidden as it is in God's highest creation. It has been stated that every sponge contains a large number of separate cells which carry on the operation of circulation and respiration, and may be likened to the heart and lungs of an animal of a higher creation. Zoölogists claim that each one of these cells represents a separate animal, living in a common structure. However this may be, it is an interesting fact that the sponge has the power of secreting ova that grow in large numbers in little sacks until they have reached a certain stage [Pg 173] of progress, when they are expelled from the mother sponge and turned adrift in the great ocean to struggle for their own existence. These eggs do not differ much in their structure and composition from an ordinary hen's egg, except that there is no shell, only a skin provided with little fibers called cilia, that project from it, and by the movement of these the embryo sponge is able to propel itself through the water. It thus lives until it has reached a certain stage of development, when it seeks out a pebble or rock, to which it attaches itself at one end—preparation for which has been made by its peculiar structure during its life when it was free to float around through the water. It is now a prisoner and chained to the rock it has selected for the foundation of its home. Having no longer any use for the little cilia, which enabled it to swim through the water, it now loses them. Here is a beautiful illustration of how nature provides for the necessities of the smallest things, and how when the necessity that demanded a certain condition passes by the condition passes with it. The embryo begins to show a fibrous development, which is the beginning of the framework of a new sponge. Evolution goes on, every step of which is as mysterious as a miracle, until the growing thing is a full-grown sponge, equipped with the means for respiration, circulation, feeding, digestion, and reproduction. [Pg 174]

Sponges grow in the bottom of the sea at different depths. They are obtained by divers who make a business of gathering them. The best sponges are called the Turkish sponge, which are very soft and velvety, and may be bleached until they are nearly white by subjecting them to the action of certain acids. The divers become very expert, but they do not have the modern equipments of a diving suit. The Syrian divers in the Mediterranean go down naked with a rope attached to their waists and a stone attached to the rope to cause them to sink, together with a bag for carrying the sponges. They have trained themselves until they can remain under water from a minute to a minute and a half, and in that time can gather from one to three dozen sponges. The ordinary depth to which they descend is from eight to twelve fathoms. But a very expert diver will go down as far as forty fathoms. The better class of sponges are said to grow in the deeper waters. The coarse inferior sponges are called the Bahama sponge. This sponge is of a peculiar shape, growing more like a brush, with long bristly fiber.

The trade in sponges is quite large. The consumption in Great Britain alone amounts to about $1,000,000 per annum.

The sponge as an animal possesses many advantages over his more aristocratic neighbor, man. [Pg 175] He breathes but he has no lungs, and therefore cannot have pneumonia. He digests his food, but he has no stomach, and therefore never has dyspepsia, gastritis, or any of the many ailments that belong to that much abused organ. He has no intestines, and therefore cannot have appendicitis or Asiatic cholera or any of the long train of diseases incident to those complicated organs. He has no nervous system—oh, happy sponge!—therefore he cannot have nervous prostration, hysteria, or epilepsy. He has no use for doctors, and therefore has no unpleasant discussions with his neighbors about the relative merits of the different schools of medicine. If he has any predilections in the way of "pathies" we should say that he is a hydropath. While he is a great drinker, he is not at all convivial—he drinks only water, and takes that in solitary silence. He sows all his wild oats when he is very young, while he has the freedom to roam at will. He soon tires of this, however, for he selects the rock that is to be the foundation of his future home and there settles down for life, "wrapt in the solitude of his own originality." He is not troubled with wars or rumors of wars. His eyes are never startled or his nerves shaken by the scare headlines of yellow journalism. The one sensation of his life, if sensation he ever has, is when a great ugly [Pg 176] creature of some Oriental clime comes down to his home and tears him away from his native rock, carries him to the surface, and there literally "squeezes the life out of him." He finally dies of the "grip," and here he sinks to the level of his more aristocratic neighbor.

But there is another side to our philosophy. If the sponge is exempt from all these ills that we have enumerated it is because he is incapable of suffering and is therefore incapable of enjoyment. Those beings that have the ability to suffer most have also the ability to enjoy most. The higher the type of civilization the greater possibilities it offers for real enjoyment—also for real misery. This being true, it should be the aim of highly civilized people to eliminate as far as possible those things that make for misery, and cultivate those things that make for happiness in the highest and best sense.

CHAPTER XXII. [Pg 177]

WATER AND ICE.

We now have entered upon a subject that is of intense interest, studied from the standpoint of facts as they exist to-day and of history as we read it in the rocks and bowlders that we find distributed over the face of the earth.

The whole northern part of the United States extending to a point south of Cincinnati was at one time covered with a great ice-sheet, traces of which are plainly visible to anyone who has made anything of a study of this subject. The glaciers now to be seen in British Columbia and Alaska, great as they seem to one viewing them to-day, are by comparison with what once existed simply microscopic specks of ice. Glaciers, like rivers, flow by gravity, following the lowest bed and lines of least resistance; the difference being that in the one case the flow is rapid, while in the other it is scarcely visible, except by measurement from day to day. Before entering upon a description of the law that governs the flow of glaciers, let us stop and give a little study to the phenomena of [Pg 178] water as exhibited when it is at the freezing point. Water is such a large factor in the make-up of our globe and the air that surrounds it that it becomes a very interesting and important study to anyone who wishes to understand the phenomena of nature that are closely related to it.

As all know, pure water is a compound of two gases, oxygen and hydrogen, combined in the proportion of two atoms of hydrogen and one of oxygen.

Let us now study this fluid in its relation to heat. The reader is referred to the chapters on heat in Vol. II., where it is stated that heat is a mode of motion. It is also stated that heat is a form of energy, and that energy is indestructible, that an unvarying amount of it exists in some form or another throughout the universe. It is not always manifested as heat or electricity, although both of these are always in evidence as active agents of force. Much of the energy is simply stored—all the time possessing the ability to do work or to be converted into any of its known forms, such as heat, light, electricity, or mechanical motion. A weight that is wound up has required a certain amount of energy to elevate it to the position that it occupies. While in its elevated position it possesses energy, although not active. Energy in this form is called potential (possible) energy, [Pg 179] and has the power to do work if released. Active energy is called kinetic (moving) energy, and the sum of these two energies is a constant quantity.

We will now study energy as it is related to water in the form of heat. There is a kind of heat called "latent heat," which is not heat at all, but stored energy, waiting to be turned into heat, or light, or some other active form. Properly speaking, heat is a movement of the atoms of matter, the intensity of which is measurable in degrees, and called its temperature. To use the term latent heat as meaning concealed heat, which must reappear as heat, is a misnomer and is very misleading. If it is proper to call a wound-up spring or weight latent heat then its present use is a correct one. What was formerly termed latent heat is simply a form of potential energy. When sensible heat that is measurable, as temperature, disappears in the performance of some sort of work, especially in connection with certain phenomena relating to water, we call it—or rather miscall it—latent heat: but the phrase would better be "stored energy."

The action of water under heat is very peculiar, and in order to get a correct understanding of the phenomena exhibited in glacial action we also need to understand the phenomena of water at the freezing point. As is well known, fresh water freezes at 32 degrees Fahrenheit, and at the [Pg 180] moment of freezing there is a sudden expansion to such an extent that a cubic foot of ice will occupy a much larger space than it will in the form of water; and because it occupies so much larger space it is lighter than the same bulk of water would be, and therefore it floats in water.

At the point of freezing, the thermometer if placed on the ice will register 32 degrees. If the ice is allowed to melt, the water at the moment of liquefaction would be found to register the same degree of temperature as the ice when first frozen. And yet there has been a vast expenditure of energy between the points of liquefaction and congelation, notwithstanding the temperature of ice may be lowered, after it is formed, many degrees, which is measurable by the thermometer. Suppose we take a piece of ice which is 10 degrees below the freezing point and insert in it a thermometer. If now we apply heat to this ice the thermometer will gradually rise until it reaches the melting point at 32 degrees Fahrenheit, where it will stand until all the ice is melted. The application of heat is going on steadily, but there are no indications of movement in the mercury until the last trace of ice with which it is in contact has been liquefied. After the ice is all melted, if the application of heat to the body of liquefied ice be continued, the column of mercury will resume its movement upward until it reaches the boiling point, where it is again arrested. And no [Pg 181] matter how much heat is applied to the boiling water, if in an open vessel, the thermometer remains the same until all the water is evaporated. Here are two curious facts, and they are facts that, if we can master them, will serve as a key to the understanding of much that is mysterious in nature.

It will be our endeavor to give the reader a mental picture of what is taking place during the time the ice is melting and the thermometer is stationary. Do not suppose that you can understand this, even so far as it is understandable, by a casual reading without thought. No man was ever yet able to present a picture to the mind of another, however clearly and simply it may be done, unless that other mind is receptive. When a photographer trains his camera upon an object, however intense the light may be and however clean-cut the picture that is thrown upon the plate in the camera, unless that plate is properly sensitized so that the picture may be impressed upon it, all of the other conditions are in vain. The reader is always a part of the book he is reading.

CHAPTER XXIII. [Pg 182]

STORED ENERGY IN WATER.

In our last chapter we traced the upward movement in the mercury of the thermometer from 10 degrees below the freezing point up to the boiling point of water. We found that the thermometer was arrested at 32 degrees and remained stationary at that point until all the ice was melted, notwithstanding the fact that heat was being constantly applied. After the ice is all melted the mercury moves upward until it reaches the boiling point of water, where the movement is again arrested, and although the heat is being continuously applied, it remains stationary until all the water is evaporated. If we push the process still further, with a sufficient application of energy we can separate the vapor molecules into their original elements, oxygen and hydrogen.

Let us go back now to the freezing point of water and see what is becoming of the heat that is consumed in melting the cake of ice, and still does not produce any effect upon the mercury in the thermometer. Sensible heat, as before stated, is a movement of the atoms of matter, and [Pg 183] temperature, as it affects the thermometer, is a measure of the intensity of motion exhibited by these atoms.

In the experiment of the block of ice that in the beginning is 10 degrees below the freezing point, as shown by the thermometer, the molecules have a definite intensity of motion. The intensity of this motion increases when heat is applied until it reaches 32 degrees, when it remains stationary until all of the ice is melted. At this point there is a rearrangement of the molecules of water as it assumes the liquid state. To perform this rearrangement requires a certain amount of work done, which is analogous to the winding up of a weight to a certain distance. There has been energy used in winding up the weight, but that energy now is not destroyed, nor still in the form of heat, but is in the potential state—ready to do some other kind of work. So, the heat that has been applied to the melting ice has been utilized during the process of its liquefaction in rearranging the water molecules and putting them in a state of strain, so to speak, like the weight that is wound up to a certain height. There is a certain amount of potential energy that is stored in the molecules of water that will be given up and become active energy in the form of heat, if the water is again frozen. To melt a cubic foot of ice requires as much heat as it would to raise a [Pg 184] cubic foot of water 144 degrees Fahrenheit. But, as we have seen, while all of this energy is absorbed as heat, it is not lost as energy. It ceases to be kinetic or active and becomes potential energy. This (let us repeat) has been called latent heat. The term grew out of the old idea that heat was a fluid and that when it became latent it hid itself away somewhere in the interatomic spaces of matter and ceased to be longer sensible heat. It came into existence in the same manner and occupies the same place in the science of heat that the word "current" does in the science of electricity: both of them are misnomers.

When the ice is all melted potential energy is no longer stored, but is manifested in the sensible heating of water, the degree of which is measurable by the thermometer, until it reaches the boiling point, where it is again arrested. All of the surplus heat above that temperature is consumed in rending the liquid water into moisture globules that float away into the air, each one of them charged with a store of potential energy. Let us follow this vapor spherule as it floats into the upper regions of the atmosphere. Myriads of its fellows travel with it until it reaches a point where condensation takes place, when it collapses and unites with other vapor particles to form water again. In doing this the heat that was expended upon it to disengage it (whether the heat [Pg 185] was artificial or that of the sun's rays) now reappears either as sensible heat or as electricity, or both. And this is what is meant in meteorology by latent heat becoming sensible heat at the time of condensation; in fact, it is stored or "potential" energy becoming active or kinetic, and assumes the form of heat or electricity, as before stated. We have thus reviewed the matter of the foregoing chapter in order to follow the course of the stored energy from the melting of the ice to the vapor, and back again to water: to doubly impress the fact that the energy used was not consumed, but still exists and is ready for further work.

During the progress of a hailstorm, it has been stated, one of the factors that is active to produce this phenomenon is the intense ascensional force that is given to the moisture-laden air, caused by intense heat at the surface of the earth. This condition forces the moisture vapor to higher regions of the atmosphere than is the case with the ordinary thunderstorm. Another factor that is undoubtedly active in producing hail under these circumstances is that when condensation takes place in the higher regions, and is therefore more energetic on account of the intenser cold, the potential energy that is set free by the moisture spherules takes, in a larger degree, the form of [Pg 186] electricity rather than heat, as is the case under more ordinary circumstances. While in the end this electrical energy becomes active heat, it does not for the time being, and thus favors the ready congelation of the condensed moisture into hailstones. Hailstorms are always attended by incessant thunder and lightning, and this fact favors the theory advanced above.

It will be easily seen from a study of the foregoing what a wonderful factor evaporation (which is a product of the sun's rays) is, in the play of celestial dynamics. It ascends from the surface of the earth or ocean laden with a stored energy, the power of which no man can compute, and beside which gravitation is a mere point. In the upper regions of atmosphere this potential force under certain conditions is released and becomes an active factor, not only in the formation of cloud and the precipitation of rain, hail, and snow, but it disturbs the equilibrium of the air and sets that in motion.

Certain physicists deny that evaporation has anything to do with atmospheric electricity. They tell us that it is caused by the arrest of the energy of the sunbeam by the clouds and vapor in the upper atmosphere. We admit that a part of the energy is so arrested, and is stored, for the time, in moisture globules by a process of cloud evaporation to transparent vapor again. Yet this does [Pg 187] not hinder the same process from going on at the surface of the earth wherever there is water or moisture. But they tell us that the electroscope does not show any signs of electrification in the evaporated moisture. Of course it does not. The electroscope is not made to detect the presence of energy except when set free as electricity.

A wound-up spring does not seem to be electrified, but if it is released the energy stored in it will be transformed into electricity if the conditions are right. Just so, the energy required to put the moisture spherule into a state of strain is latent until some power releases it, when it reappears as active energy of some form.

We have now followed the relation of heat to water from a point 10 degrees below freezing up to where it was forced into its original gases, oxygen and hydrogen. These gases have stored in them a wonderful amount of potential energy. When one pound of hydrogen and eight pounds of oxygen unite to form water the mechanical value of the energy given up at that time in the form of heat is represented by 47,000,000 pounds raised to one foot in height. And this is the measure of the energy that was put into nine pounds of water to force it from a state of vapor into its constituent gases. After the combination of the gases into a state of vapor the temperature sinks [Pg 188] to that of boiling water. The amount of energy given up in condensing the nine pounds of vapor into nine pounds of water is equal to 6,720,000 foot-pounds. If this nine pounds of water is now cooled from the boiling point to 32 degrees Fahrenheit we come to the final fall, where the potential energy that is stored in the operation of melting ice is given up suddenly at the moment of freezing, which in nine pounds of water is 993,546 foot pounds.

Professor Tyndall, in speaking of the amount of energy that is given up between the points where the constituent gases unite to form nine pounds of water and the point where it congeals as ice, says: "Our nine pounds of water, at its origin and during its progress, falls down three precipices —the first fall is equivalent in energy to the descent of a ton weight down a precipice 22,320 feet high-over four miles; the second fall is equal to that of a ton down a precipice 2900 feet high, and the third is equal to a fall of a ton down a precipice 433 feet high. I have seen the wild stone avalanches of the Alps, which smoke and thunder down the declivities with a vehemence almost sufficient to stun the observer. I have also seen snowflakes descending so softly as not to hurt the fragile spangles of which they are composed. Yet to produce from aqueous vapor a quantity which a child could carry of that tender material demands an exertion of energy competent to [Pg 189] gather up the shattered blocks of the largest stone avalanche I have ever seen and pitch them to twice the height from which they fell."

When we contemplate the foregoing facts as related to so small an amount of water as nine pounds, and multiply this result by the amount of snow- and rainfall each year and the amount of ice that is congealed and again liquefied by the power of the sun's rays, we are appalled, and shrink from the task of attempting to reduce the amount of energy expended in a single year to measurable units.

Having considered water in its relation to heat in the preceding chapters, we will now take up the subject of water in its relation to ice and snowfall and the phenomena exhibited in ice rivers, commonly called glaciers.

When water is under pressure the freezing point is reduced several degrees below 32 degrees Fahrenheit. This fact has been determined by confining water in a close vessel and putting it under pressure and subjecting it to a freezing mixture, and by this means determining the freezing point under such conditions. By putting a bullet or something of that nature into the water that is subjected to pressure one can tell by shaking it when the freezing point is reached. If water is put under pressure and cooled to a point below 32 degrees, and yet still remains in the [Pg 190] liquid state, it may be suddenly congealed by taking off the pressure; this shows that the pressure helps to hold the molecules in the position necessary for the liquid state, and prevents the rearrangement of them that takes place at the moment of freezing. When the water molecules are arranged for the liquid condition they may be compared to a spring that is wound up and held in position by the heat energy that is stored in the water. And when this energy is given up to a certain degree the power that holds the spring wound up is suddenly released, when it unwinds and occupies a larger space. There is a force that we may call polar force, which is constantly tending to push the molecules of water into an arrangement such as we see when crystallization takes place—as it always does in the act of freezing. These polar forces cannot act so long as the energy in the form of heat is sufficient to hold the water in the fluid state. But the moment this energy, which tends to hold it in the fluid state, falls below that which tends to rearrange it into the crystalline form, it is overcome by the superior power of the latter force, and we have the phenomenon of solidified water.

A very interesting experiment may be performed with a block of ice by anyone when the ice is near the melting point. If a wire is put around the ice and a sufficient weight is suspended to it, [Pg 191] the pressure of the wire on the ice will gradually liquefy that portion immediately under the wire, which allows it to sink into the ice slowly, and as this process goes on the ice freezes together again behind the wire, so that in time the wire will pass entirely through the block and leave it still a solid block, as it was before the experiment began.

This is an interesting fact which it will be well to remember when we come to explain glacial action, or rather the law that governs glacial action. If we take two pieces of melting ice and bring them together they immediately congeal at the point of contact. This phenomenon is called "regelation." Ice has some of the properties of a viscous substance. It will yield slowly to pressure, especially when near the melting point, but if put under a tensional strain it will break, as any brittle substance will, so that it has the properties of both viscosity and brittleness. Ordinarily we are in the habit of treating water as a fluid and ice as a solid, but from what has gone before the reader must understand that in a certain sense ice should be treated as having semi-fluidic properties.

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CHAPTER XXIV.

WHY DOES ICE FLOAT?

Nature is full of surprises. By a long series of experimental investigations you think you have established a law that is as unalterable as those of the Medes and Persians. But once in a while you stumble upon phenomena that seem to contradict all that has gone before.

These, however, may be only the exceptions that prove the rule. It is recognized as a fundamental law that heat expands and cold contracts; that the atom when in a state of intense motion (which is the condition producing the effect that we call "heat") requires more room than when its motions are of a less amplitude. In other words, an increase in the amplitude of atomic motion is heating, while a decrease is cooling. It follows from the above statement that the colder a body becomes the smaller will be its dimensions. There are two or three, and perhaps more, exceptions to this rule, and the most notable one is that of water. Water follows the same law that all other substances do under the action of heat and cold, within certain limits only. [Pg 193] If we take water, say, at 50 degrees Fahrenheit and subject it to cold it will gradually contract in bulk until it reaches 39 degrees Fahrenheit. At this point, very curiously, contraction ceases, and here we find the maximum density of water. If the temperature is still lowered we find the bulk is gradually increasing instead of diminishing (as is the rule with other fluids), and when it reaches the freezing point there is a sudden and marked expansion, so much so that a cubic foot of ice, which is solidified water, will not weigh as much as a cubic foot of water before it freezes—hence it floats.

Let us try an experiment. Take a small glass flask, terminating in a long neck, say of four to six inches, and of small diameter. Suppose the water in the glass to be at 50 degrees Fahrenheit. Fill the flask with water until it stands halfway up the neck at 50 degrees temperature. Now immerse the flask gradually in hot water, and observe the effect. For a moment the water will lower in the neck of the tube, but this is due to the fact that the glass expands before the heat is communicated to the water and enlarges its capacity. But immediately the water will begin to rise as the heat is communicated to it, and will continue to expand up to the boiling point. Now take the flask out of the hot water and gradually introduce it into a freezing mixture made of [Pg 194] broken ice and salt. Immediately the water will begin to fall in the tube, showing that it is contracting under the cold, and it will continue to contract until it reaches a temperature of 39 degrees Fahrenheit, when it will come to a standstill and then proceed to expand as the temperature of the water lowers. When it reaches the freezing point the fluid can no longer rise in the neck of the flask, which is broken by the sudden expansion that takes place at this point.

To show what an irresistible power resides in the atoms of which the body is made, let us take an iron flask with walls one-half inch or more in thickness; fill it with water and seal it up by screwing on the neck an iron cap; now plunge it into the freezing mixture, and the first effect will be to contract the water unless it is already below 39 degrees Fahrenheit, but when it reaches that point expansion sets in, which continues to the freezing point, when a greatly increased expansion takes place suddenly. The walls of the iron flask, although a half-inch in thickness, are no longer able to resist the combined efforts of the billions upon billions of the atoms of which the water is made up, in their individual clamor for more room, hence the flask is shivered into pieces.

[Pg 195] There are one or two other substances which are exceptions to the general rule, but we will mention only one, which is the metal bismuth. If we should melt a sufficient amount to fill an iron flask, such as we have described, and subject it to the same freezing process, the flask will be broken the same as in the experiment made with the water.

A query arises, Why this phenomenon? Why does water follow a different law in cooling from that of nearly all other substances?

This is a case where it is much easier to ask a question than to answer it. When water solidifies at the moment of freezing, crystallization sets in. But what is crystallization? Crystallization is a peculiar arrangement of the molecules of matter, which takes place in some substances when they pass from the liquid to the solid form. The molecules assume definite forms and shapes, according to the nature of the substance. When water assumes the solid form under the action of cold the molecules arrange themselves according to certain definite and fixed laws, the result of which is to increase the bulk to a considerable extent over that which the same number of molecules would occupy at a temperature of 39 degrees Fahrenheit. Hence, as has been heretofore stated, a given block of solidified water is lighter than the same bulk would be in the fluid state, and this is the reason why ice floats. [Pg 196]

What would happen in case nature did not make this exception to the laws of expansion and contraction by heat and cold, in the case of water? First, our lakes would freeze from the bottom upward; as soon as the surface became frozen, or even colder than the water underneath, it would drop to the bottom, the warmer water below coming up by a well-known law—that the warmer fluid rises and the colder falls. This circulation would continue until ice began to form, which would immediately drop to the bottom, and this process would go on until the whole mass were frozen solid. In the same way our rivers in the northern climates would freeze from the bottom, and in time our valleys would fill up with ice to a thickness that the summer's sun would never melt, and gradually all north of a certain zone would become a great glacier, rendering not only the lakes and rivers but also the surface of the earth unfitted for animal life.

Those who believe that the laws of nature are the creations of a beneficent and all-wise Intelligence will see in this exception to the general law in the case of freezing water a striking evidence of design. But those who have no such belief will say it is a most fortunate though fortuitous circumstance (a saying they will have to make, regarding thousands of other things in nature), and go on floundering in the interminable sea of "I don't know." [Pg 197]

The atom when it is acting under the direction of a fixed law is a giant in strength. And when its individual strength is multiplied by billions upon billions the combined energy exerted produces a power that is irresistible. Not only has nature endowed these atoms with this wonderful power, but she has also willed that they arrange themselves in lines of beauty. In confirmation of this we need only to study the work of the frost upon our window panes. As we lie in our beds on a cold night and exhale moisture from our lungs it settles upon the window panes of our bedrooms, where Nature—that wonderful artist—forms it into beautiful pictures that gladden our eyes when we awake:

> Most beautiful things; there are flowers and trees,
> And bevies of birds, and swarms of bees,
> And cities, and temples, and towers, and these
> All pictured in silver sheen.

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CHAPTER XXV.

GLACIERS.

Glaciers are rivers of ice, and, like other rivers, some of them are small and some very large. They flow down the gorges from high mountains, whose peaks are always covered with a blanket of eternal snow. Summer and winter the snow is precipitated upon these mountains, and from time to time the heat of the sun's rays softens the snow, when by its great weight it packs more closely together until it is, in many cases, formed into solid ice-cakes. If we take a quantity of snow or a quantity of granulated ice and put it under a sufficient pressure we can produce clear solid ice, and it is by this process that ice is formed out of the snow and hail that falls continually upon the tops of these glacial mountains. We have seen that ice possesses certain viscous or semi-fluidic properties and that it will yield to pressure, but if we put it under sufficient tensional strain it snaps like glass or any other brittle substance. As the snows upon these mountains pile up higher and higher the pressure becomes greater and greater until it reaches a point where the mass begins to move gradually down the mountain side, following the gulches and defiles that [Pg 199] furnish a path of least resistance to its flow.

At the sides and bottom, where there is contact with the earth, the movement is slower than it is at the surface and in the middle of the ice stream. If there were no curves in the ravine or gulch through which it flows the point of greatest movement would be confined to the middle of its width. But in flowing through a winding gulch the most rapid flow follow the lines of greatest pressure, and this line is deflected from side to side, so that the line of greatest flow is more winding than is the bottom of the valley through which it flows. (The movement is called a "flow," but it is very sluggish, only a few inches in a day, as will appear later.)

If the bottom and sides of the valley were straight the surface of the ice would be comparatively even; I say comparatively, for as compared with a smooth surface it would be very rough; but there would be none of the great crevasses or openings now to be found in the ice, which sometimes are very large and extend to a great depth. If in its downward course the bottom of the ravine suddenly becomes steeper, the top of the ice is put under a tensional strain which causes it to break, thus forming the crevasses.

If at the bottom of the descent the valley curves upward or preserves the straight line for a [Pg 200] considerable distance, these crevasses will close at the top and perhaps open at the bottom, and the blocks of ice will freeze together to such an extent that the water caused by the melting ice will flow on top until it comes to another crevasse, where it runs through to the bottom or underflow, which is always an attendant of a glacier.

The glacier continues its flow down the mountain side till in some cases it reaches quite to the valley below, and in others it stops short, as the action of the sun is so great that it melts entirely away at this point as fast as it moves down. In the winter time, however, the glacier may flow far down into the valley and will accumulate greatly in bulk, owing to the fact that the ice forms from the precipitation of snow on top faster than it melts away underneath. If it were not for the fact that in summer the glaciers melt faster than they form, the whole valley would in time become a great river of ice. It is the case in Switzerland that some years the accumulation is greater from snowfall than diminution from melting. If this condition should continue it would become a serious matter.

In the downward flow of a glacier—slow as it is—there is an exhibition of wonderful power; great bowlders are torn from their beds and either ground to powder or carried down to the end of the [Pg 201] glacier, to be dropped with the other débris that has been carried there by the same force, forming an accumulation that geologists call the "moraine." Of these moraines we will speak more fully later on.

It was the privilege of the writer some years since to visit the great glaciers of Switzerland and to some extent study their action. Some rivers have their origin chiefly in melting glaciers. They start as ice rivers and end in rivers of water. The effects during the great ice age of some of these glacial rivers, which are now extinct, are very remarkable; we shall have occasion to refer to them when we come to treat of the glacial period.

There is a glacial river flowing which is fed largely by the great Rhone glacier in Switzerland. The water from this river is almost as white as milk, which is occasioned by the grinding action of the great ice blocks on the rock as it flows down the sides of the mountain. These glacial rivers are much higher in summer, of course, than in winter, some of them having not only an annual fluctuation, but a diurnal one. The former is caused by the cold of winter, and the latter because it freezes to some extent at night and checks the flow of water. The difference between day and night in these high altitudes is very marked. While it is extremely hot in the sun, it is cool the moment we step into the shade. [Pg 202]

I remember walking across one of the glaciers in the Alps, called the Mer de Glace, one clear day in summer, when I suffered so much from the heat, although standing upon a sea of ice, that it was necessary to carry an umbrella. In fact, during my stay there was a case of sunstroke that occurred upon this same glacier. This intense heat during the day melts the surface of the ice, which forms streams that run along on the top of a glacier until they come to a crevasse or riffle in the ice river, where they plunge down and become a part of the glacial stream that is flowing underneath the ice.

The speed at which these ice streams flow varies greatly with the size of the glacier as to width and depth and the steepness of the grade, and many other conditions. In its movement the glacier is constantly bending and freezing and being torn asunder by tensional strain, yielding and liquefying at other points by pressure, only to freeze again when that pressure is removed. This, taken in connection with the friction of the great ice bowlders, produces a movement that is exceedingly complicated in its actions and interactions.

According to Professor Tyndall's investigations, the most rapid movement observed in the glaciers of Switzerland is thirty-seven inches per day at the point of greatest movement. From [Pg 203] this point each way the motion gradually diminishes until it reaches the sides of the glacier, where the motion is not more than two or three inches.

The great North American glaciers move at a much higher rate of speed. We are indebted to Dr. G. Frederick Wright, author of "The Ice Age in North America," who spent a month studying the Muir glacier in Alaska, for many details concerning that great ice river. This glacier empties into Muir Inlet, which is an offshoot of Glacier Bay. It is situated in latitude 58 degrees 50 minutes and longitude 136 degrees 40 minutes west of Greenwich. The bay into which this glacier empties is about thirty miles long and from eight to twelve miles wide. This bay, with its great glacier, has a setting of grand mountain peaks. I cannot do better than to quote the words of Dr. Wright when he describes the location of this glacier. Dr. Wright lived for a month in a tent on the edge of this bay, a short distance below the face of the great glacier, where the icebergs fell off every few minutes into the deep water.

He says: "To the south the calm surface of the bay opened outward into Cross Sound twenty-five miles away. The islands dotting the smooth surface of the waters below us seemed but specks, and the grand vista of snowclad mountains guarding either side of Chatham Strait seemed [Pg 204] gradually to come to a point on the southern horizon. Westward toward the Pacific was the marvelous outline of the southern portion of the St. Elias Alps. The lofty peaks of Crillon, 15,900 feet high, and Fair Weather, 15,500 feet high, about twenty-five miles away and about the same distance apart, stood as sentinels over the lesser peaks."

The Muir glacier might be likened to a great inland sea of ice fed by many tributaries or ice rivers. It narrows up at the point where it empties into Muir Inlet to 10,664 feet, or a little over two miles. An enormous pressure is exerted at this point, which causes the ice to flow in the central portion at the rate of about seventy feet per day. There is a continual booming, like the firing of a cannon, going on, caused by the bursting of some great iceberg either before it takes its final leap into the water or at the moment of its fall. At the point where these great icebergs drop off into the water they stand like a solid wall 300 feet above its surface. Dr. Wright says: "From this point there is a constant succession of falls of ice into the water, accompanied by loud reports. Scarcely ten minutes, either night or day, passed during the whole month without our being startled with such reports; and frequently they were like thunder claps or the booming of cannon at the bombardment of a besieged city, and this though our camp was two and one-half [Pg 205] miles below the ice front.... Repeatedly I have seen vast columns of ice extending up to the full height of the front topple over and fall into the water. How far these columns extended below the water could not be told accurately, but I have seen bergs floating away which were certainly 500 feet in length."

It is estimated that the cubical contents of some of these icebergs are equal to 40,000,000 feet. This great glacier is fed by the constant precipitation of snow upon the sides and peaks of the high mountains that surround its vast amphitheater, which is floored with icebergs. Wonderful as this seems to us to-day, it is scarcely a microscopic speck of what existed during the ice age all over the northern part of North America.

There are many other great glaciers in the mountains of the Pacific coast. Some years ago I saw one of these immense glaciers in British Columbia, from a point called Glacier Station, in the Selkirk Mountains, on the Canadian Pacific Railroad. It was during the month of August, when all of the region was pervaded by a dense smoke occasioned by burning forests. This glacier is a very showy one, owing to the steepness of the side of the mountain and its great breadth. All the glaciers that exist to-day are gradually receding, and are destined eventually to entirely [Pg 206] disappear, unless there is a change in meteorological conditions, which some scientists claim will be the case if we only wait long enough, when again all this northern country will be covered with a great ice sheet. There is no doubt in regard to the facts concerning a glacial period that must have existed in the ages past. To anyone who has made a study of the subject there is not wanting abundant evidence to prove that this northern country was at one time enveloped with a great ice sheet of enormous thickness. The conditions that existed to bring about such a state of things have been the subject of much speculation by philosophers, but no one, as yet, has arrived at any very satisfactory conclusion. Many theories have been advanced, some of them not worth considering, while others have many things that give them a show of plausibility. But all of them have what is said of the Darwinian theory, "a missing link." It will be interesting, however, and also instructive, to know what can be said in favor of a set of conditions that would produce such momentous results.

CHAPTER XXVI. [Pg 207]

EVIDENCES AND THEORIES OF AN ICE AGE.

There is abundant and unassailable evidence that at one time, ages ago, a vast ice sheet covered the whole of the northern part of North America, extending south in Illinois to a point between latitudes 37 and 38. This is the most southerly point to which the ice sheet reached. From this point the line of extreme flow runs off in a northeasterly and northwesterly direction. The northeasterly line is through southeastern Ohio and Pennsylvania, striking the Atlantic Ocean about at New York, thence through Long Island and up the coast of Massachusetts. Northwesterly it follows the Mississippi River to its junction with the Missouri, which it crosses at a point some miles west of this junction, following the general course of this river a little south of it through the States of Missouri, Nebraska, Dakota, and Montana. The lines, especially the northeasterly one, are very irregular, shooting out into curves and then receding. This line of extreme ice flow is marked by glacial drift so prominently that no one who has studied glacial action can doubt for a moment what was the cause of these deposits. The line is called the [Pg 208] "terminal moraine." By examining a map of North America and tracing the line of the moraine as we have described it, it will be seen that about two-thirds of North America was at one time covered with ice to a greater or less depth. How deep, is simply a matter of conjecture, but in the central portions of the great glacier, where was the bulk of snowfall, it must have reached a depth of several miles to account for the enormous pressure that would be required to carry the ice so far southward.

But let us go back and define what is meant by a moraine. A moraine is a name given to the deposits that are of stone, gravel, and earth that have been carried along by the movement of the glaciers and deposited at their margins, sometimes piled up to great depths. The composition of these moraines is determined of course by the nature of the country over which the stream of ice is flowing. Bowlders of enormous size have been carried for hundreds of miles, and the experienced geologist is able to examine any one of them and tell us where its home was before the glacial period. Moraines are divided into different classes according to their position and constitution. The moraine found at the extreme limit of ice-flow is called the "terminal" moraine, [Pg 209] as before mentioned. Those that are found inside of this line and between two flows are called "medial" moraines. There is a subdivision called "kettle" or "gravel" moraines, which are very prominent in northern Illinois and southern Wisconsin, and may be said to culminate in the vicinity of Madison. This moraine is a great deposit of gravelly soil. Where this moraine exists the face of the country is covered with "kettle holes" of all sizes and shapes, and in some of them there are small lakes, while others are dry. The great chain of inland lakes that are found in southern Wisconsin and northern Illinois were formed by deposits of ice that had been covered by glacial drift, gravel and otherwise, brought down and deposited upon these masses of ice which gradually melted away, leaving a depression at the points where they lay, while the drift that was piled around them loomed up and became the shores of the lake. This is substantially Dr. Wright's theory, who studied the formation of these "kettle holes" at the mouth of the Muir glacier. This enthusiastic glacialist has spent many summers tracing the terminal moraine with its fringe along the lines heretofore indicated. He is, therefore, entitled to speak with authority on matters of glacial action.

The part of the country that has been plowed over by these glaciers is called the glaciated area and the rest the unglaciated. The whole of North America north of the line of the terminal [Pg 210] moraine that we have traced is a glacial region, with the exception of a few hundred square miles chiefly in Wisconsin, where the ice seemed to have parted and passed around this area, coming together again on the south side of it. The ice probably did not reach the extreme limit that shows glacial deposit, but undoubtedly the effects of it are seen for some distance to the south, owing to the fact that during the time it was melting great quantities of water flowed away from the extreme edge of the ice, carrying with it more or less of the glacial drift, which was deposited for some distance to the south. When the ice receded it undoubtedly paused at different points, where it remained stationary for a long period of time. I mean stationary at its edges, for the flow of ice was continually moving, but in its progress southward it came to a point where the heat was sufficient to melt the ice as fast as it arrived at that point. The on-moving ice was continually bringing with it the débris that it had gathered up at different points on its journey, so that it is easy to see how these moraines could accumulate to a greater or less depth at the margin of the ice flow, which would be determined by the duration of the period it remained stationary. This, however, is only one factor, as the surface of the earth in some parts of the country would be [Pg 211] more easily picked up and carried than in others; therefore, the drift accumulated much more rapidly in some sections than in others.

Another factor that was active in the more rapid accumulation at certain points was the speed at which the ice moved, and this would be determined by the pressure that was behind it, and there would always be lines of unequal pressure existing in such a great glacier as must have existed when these moraines were formed.

As an instance of the difference in the glacial deposits that are made in different periods during the time of the melting of the great ice sheet we may compare the Kettle Moraines of Wisconsin with the clay deposit mixed with broken gravel that we find along the west coast of Lake Michigan. Those whose homes are situated between Winnetka and Waukegan on the lake shore have the foundations of their houses set in glacial drift that was shoved into position by the ice during the glacial period.

Anyone who makes an examination of the bluffs along the shore of this lake will notice that there is no stratification whatever to the deposit such as will always be found in an unglaciated region. Going west from the bluff a few miles we come down to the prairie level, where we find the soil of an entirely different nature. The soil of the prairies of Illinois and Iowa is probably to a great [Pg 212] extent a water deposit. It is the kind we find in the bottom of a pond that has stood for many years, and it would seem that at some period all this prairie country with the black soil was the bottom of a great lake.

The facts of a glacial period are beyond question, but when it occurred, and how it occurred are questions that many have tried to answer. So far, all that we can say of them is that some of them are shrewd guesses. The evidences adduced for determining the time, are the erosion caused by rivers and streams since the ice subsided. Some of the rivers and outlets of lakes had their courses changed by the action of the ice, so that when it subsided new water courses were formed, and the erosion that they have produced from that time to the present furnishes the data for determining the time since the subsidence of the ice at any particular point. For instance, Niagara Falls was undoubtedly at one time situated at Queenstown, a number of miles below its present position. And the time that it has taken to grind out the great gorge that exists between that point and the present falls is approximately a measure of the time that has elapsed since the subsidence of the ice at that point. Various estimates have been made to determinate the rate of erosion. The earlier ones put the time at about 35,000 years. But there are later investigators [Pg 213] who make the time much shorter, not over 10,000 years.

So much for the time; but you ask What about the occasion, or cause? This is a question that many have attempted to answer, there having been eight or ten theories promulgated with regard to the cause of the glacial period, but no one of them is entirely satisfactory, and only two or three of them are deserving of much discussion. It is always interesting to know what people think, however, even if we do not agree with them.

The first theory named is that the glacial period is due to the decrease of the original heat in our climate. This theory can be dismissed by saying that the planet was cooling at the time and has been cooling ever since, and that the reasons for an ice age are greater now than then, on that theory. Another theory assumes that at some former period there was a greater amount of moisture in the atmosphere; while this of course would be the occasion for greater precipitation of snow, it does not account for the changing conditions that would produce the ice effect. That there was a preglacial period there is abundant evidence, in buried forests, the filling up and changing of river beds, and other evidences that will be referred to further on. This theory, unmodified and stated broadly, is not satisfactory. Another way of accounting for the glacial [Pg 214] period is the change in the distribution of land and water, which is supposed to affect the distribution of heat over the earth's surface. There is much in this theory that commends itself as plausible. Another theory supposes that the land in northern Europe and America was elevated to a higher level at that time than it is now. Others attribute it to variation of temperature in space and of the amount of heat radiated by the sun. The final theory for accounting for the ice age is attributed to what is termed the precession of the equinoxes. In short, the precession of the equinoxes means that the division between summer and winter is changing gradually, so that during a period of 10,500 years the summers are growing longer in the northern hemisphere and the winters shorter. We are now in the period of long summers, but in another 10,000 years we shall be in the period of short summers and long winters. This difference of time between the winters and the summers is supposed to be sufficient to change the thermal conditions sufficiently to produce an ice age.

It is true that the conditions now are very evenly balanced, so much so that in Switzerland the glaciers will increase for some years together, when the conditions will change, causing them to gradually recede. Several of the theories that have been advanced present evidences that are entitled to careful consideration, but none of them can be said to be entirely satisfactory. It is [Pg 215] well known that the chief factors in the production of glaciers are moisture and cold. Cold alone is not sufficient; neither is moisture, unless we can precipitate it in the form of snow. Cold is opposed to the production of moisture, and this is a flaw in the argument presented by the last theory, unless we can couple with it another set of conditions which we will discuss later.

The solution, if it is ever reached, is perhaps more likely to be found in the realm of meteorology than geology.

It is unnecessary to change the conditions of temperature or the amount of moisture now existing in order to produce the great glacier again, provided this moisture could be precipitated, enough of it, in the right place as snow. For instance, if in Switzerland, where the conditions are nearly balanced, the annual precipitation could be slightly increased we should have a condition that would precipitate more snow in winter than would melt in summer. And the glaciers would gradually accumulate in size until they would fill the valleys and gorges to the same extent as formerly prevailed. There only needs to be such a change in the meteorological conditions as will cause a greater precipitation in that part of the globe favorable to glaciers, as, for instance, in the northern part of North America toward Alaska. This might be produced by a change in the [Pg 216] conditions of the equatorial current, so that evaporation would be more rapid in the northern Pacific than it now is. When we consider that evaporation increases in proportion as the heat increases, we can see that heat is just as important a factor in the production of glaciers as cold. If evaporation could be increased in the Pacific Ocean west of Alaska, which would be carried by the wind over the mountains upon the land, and precipitated as snow, the great glaciers in that region would begin to grow instead of gradually receding, as is the case at present, and this without any change in the temperature of the world as a whole or in the amount of heat received from the sun. One can readily see how changes in the elevation of the bottom of the ocean would have such an effect upon the tropical stream as would either increase or decrease the temperature of the thermal river that flows up the western coast of Alaska.

Whatever may have been the cause that created the great ice age in North America, so that a sheet of ice covered considerably more than half of the continent, there is no doubt in regard to the fact of the existence of such an age, and it will be interesting to study some of the physical changes that have been made by the ice at that period on the surface of the glaciated area.

CHAPTER XXVII. [Pg 217]

GLACIAL AND PREGLACIAL LAKES AND RIVERS.

Since the recession of the ice, preglacial lakes have been filled up and are now dry land, and river beds have been changed so that new channels have been cut and new lakes have been formed. Even the imagination, that wonderful architect, with all its tendencies to exaggeration, palls in its attempt to give expression in measured quantities to the mighty power exerted by the great glacier or combination of glaciers that existed in comparatively recent times. I say recent times, because even 10,000 years is only a mere point of time when compared with the actual age of our globe.

Some years ago, in company with Dr. Wright, author of the "Ice Age in North America," I visited Devil's Lake near Baraboo, Wis. At this point are striking evidences of the work of the ice age. Before the glacial period the Wisconsin River made a detour some miles west of its present [Pg 218] channel through the high hills in the region of Baraboo. The hills on each side of Devil's Lake are very precipitous and are formed almost entirely of rocks. The river at that point passed between two of these hills. When the ice flowed down it surrounded these hills, yet did not sweep over their tops, but left great piles of glacial drift, both at the points where the river channel entered the hills and where it emerges from them. The channel between the hills was protected and not filled with the débris. Therefore a deep basin was left, which is kept filled by the watershed furnished by the surrounding hills. This lake recedes many feet during the summer, but it is again filled up by the rains and snows of winter. There is no considerable stream either flowing into or out from it. It is a lake formed by the glaciers, but in a different way from those in the gravel deposits at other parts of southern Wisconsin and northern Illinois.

There are hundreds and perhaps thousands of lakes that have been formed in one way or another through the power of glacial action. These smaller inland lakes, so many of which are seen in northern Illinois, southern Wisconsin, and Minnesota, are due almost entirely to the great deposits of glacial drift that have been transported with the ice. Wherever these "kettle holes" are found large bodies of ice have become anchored, while the ice behind it has carried the drift [Pg 219] until it is covered over and piled up at the sides. When these ice mountains melted away depressions were left which in some cases have resulted in lakes, and in others simply dry kettle holes. This process has been hinted at in a former chapter, but we give it here as one of the kinds of lakes formed during the glacial period. They are found everywhere that glacial action has prevailed. They are found in great abundance in some parts of New England on the margin of the terminal moraine. These lakes, however, are comparatively insignificant as compared with the great inland seas like Lake Superior and Lake Michigan, that undoubtedly owe their origin largely to the ice age.

There are other factors, however, that enter into the formation of the great chain of lakes on the northern boundary of the United States besides those mentioned, that have brought into existence the smaller inland lakes.

Glacial lakes may be divided into three classes. Those found in the "kettle holes" of the terminal or medial moraines, and those that are formed by the deposition of the glacial drift, as, for instance, Devil's Lake, and those that are caused by ice forming dams across the valley of a river that lasted only during the ice age. In some lakes of the second class erosion undoubtedly [Pg 220] entered into their formation as well as the piling up of glacial drift.

In order, however, that we may understand more fully the formation of these greater lakes it will be necessary for us to go back and examine the conditions that seem to have existed before the glacial period.

It is a fact well known that continents have periods of elevation and depression. There is abundant evidence that the northern portion of the North American continent was elevated to a much higher level in preglacial times than it occupies now. This is evidenced in very many ways by sounding the depths of old river beds now filled with glacial débris. The old beds show unmistakable evidences of having been worn down to their present level by the action of running water. They also prove to be many feet below the present sea-level. This fact seems to be sufficient to prove the theory of a higher elevation of the North American continent in preglacial times. It should be said here that undoubtedly the constant filling up of the ocean with the drift carried down by the rivers has somewhat raised its level, but hardly to the extent indicated by the old river beds. The question naturally arises, Where did all the dirt come from to fill up these great river beds and change the whole topography of the northern half of the continent? Dr. [Pg 221] Wright estimates that there is not less than 1,000,000 square miles of territory in North America covered with glacial débris to an average depth of 50 feet. Of course, the depth varies in different places from a few inches to several hundred feet. Of the carrying power of these great glaciers we will speak more fully in a future chapter. In preglacial times the watershed of the Mississippi and of the great rivers east of the Alleghany Mountains, the Susquehanna and Hudson, extended probably farther north than it does to-day. The larger portion of the drainage area that now finds an outlet through the River St. Lawrence at one time undoubtedly drained off through the Mississippi Valley into the Gulf and the Valley of the Mohawk into that of the Hudson.

It is supposed by those who have made this branch of geology a study that prior to the glacial period a river flowed down through Lake Superior, which connected with Lake Michigan at a point near its present outlet at Sault Ste. Marie, the channel of the river passing down through what is now the bottom of Lake Michigan, which had an outlet at the head of the lake near Chicago and flowed off into the Mississippi River. All of the lake bottoms of this great chain, with the exception of Lake Erie, are now below sea-level. The reason for this exception will appear further on. Before the ice age there was supposed to be no connection between Lake Michigan [Pg 222] and Lake Huron, as there is now, through the Straits of Mackinac.

Another preglacial river had its rise in the region of Lake Huron and flowed through an old river bed extending from the Georgian Bay in a southeasterly direction through the province of Ontario, and emptied into the present Lake Ontario. From Lake Ontario there is an old river bed running through the Valley of the Mohawk which empties into the Hudson at Troy. Neither of these two rivers, having their sources in the north, found an outlet through the present St. Lawrence River. During the time of the glacial period there is evidence that there was more than one center of snow and ice accumulation and each of these great centers probably had several subcenters. This theory has color given to it by the directions of movement shown by the glacial drift.

The rounded appearance of bowlders was caused by the grinding action of the ice. These bowlders, when they were first torn from their rocky beds by the irresistible power of ice pressure, were rough and jagged in shape, the same as any rock would be, torn from a quarry by a blast. They have been smoothed and rounded by rubbing against the moving ice and against each other in the progress of their long journey from their original homes. Where their home was [Pg 223] the geologist can immediately tell upon examination. It is only necessary then to examine the bowlders of any particular locality to determine the direction of the ice flow at that point.

There seem to have existed centers of ice accumulation to the north of all of the great lakes. And when they had grown to a sufficient height they joined at their edges, making one grand glacier, the movements of which were the resultant of the combined pressure exerted by these great centers of power, so that all of North America north of the line of the terminal moraine, with the exception of a small area (heretofore noted) chiefly in Wisconsin, became covered with one vast sheet of ice.

The glacier north of Lake Superior widened out the old river bed by a process of erosion to its present width.

There may have existed something of a lake in preglacial times, through which the river ran, but it undoubtedly owes its present width to the grinding action of the irresistible icebergs and the piling up of débris on the shores. The river bed was filled up by a glacial drift at the point of its present outlet until the lake was raised in its level much higher than that of Lake Michigan. Another glacier plowed down through Lake Michigan, widening it out to its present dimensions, [Pg 224] while the glacial drift was deposited at what is now the head of the lake, filling up the old outlet and thus making a great dam. The damming up of these great water courses was another cause for increasing the width of these lakes. In a similar way Lake Erie was formed. It is supposed, however, that this lake is entirely the product of glacial action, as there is no evidence of an old river bed in its bottom; besides, it is much shallower than the other lakes. The same action that formed Lake Erie filled up the old river bed running through the province of Ontario, so that when the ice receded Lake Erie became the new channel for the old river. The same process filled up the Valley of the Mohawk to more than 100 feet in depth and also raised the Valley of the Hudson. This caused the new channel to be made through the Niagara River and a new route to the ocean for the drainage of all the chain of lakes through the St. Lawrence. It will be seen that the bottoms of all of these great lakes to a certain extent were worn out by the action of running water, except Erie. The great glaciers widened them out, and in the case of Lake Erie scooped it out. At the same time it built great dams across the outlets which raised the surface of the water to a much higher level and caused them to form new outlets, thus changing the whole [Pg 225] face of the country over which the ice drifted.

The glaciated region of North America is among the most productive in the world, and in many respects presents a most pleasing landscape.

Other lakes besides these mentioned have been formed during the ice period through blocking the course of a river by the ice itself. Dr. Wright, during the time he traced out the line of the terminal moraine, discovered that the ice sheet crossed the Ohio River at a point near Cincinnati, where there is a great bend to the northward in the river. With the exception of this point and perhaps another point below, the edge of the great ice sheet kept a little north of the Ohio River. At this point, however, the ice seems to have filled the valley from hill to hill, which very naturally would form a great dam or lake in the Ohio Valley. Of course such a lake could not be permanent, because, when the ice melted away, it again opened the channel and allowed the water to flow off.

Some years before this discovery was made there were terraces found along the banks of the Ohio River and its tributaries that had been the subject of much speculation. It is well known that by the action of water from rainfall, earth, gravel, and other débris will wash down the side of a hill or mountain until it strikes a water level, and there it will build out a terrace near the level of [Pg 226] the water surface. The width of these terraces will be determined by the time the water has stood at that level and the extent and nature of the soil from which the débris comes. The evidences that are cited, pro and con, would fill a small volume, but it is sufficient to say here that the sum of the evidence goes to show that there was an ice dam formed at a point near Cincinnati and that it was maintained for a considerable period of time. Terraces were formed running up the Ohio and its tributaries corresponding to the level that the water must have risen to if the valley were filled up with ice. These facts, taken with the greater fact that the ice sheet actually did cross the Ohio Valley into Kentucky, as is shown by the terminal moraine, seems to prove conclusively the existence of such a lake during the period that the ice rested at its extreme limit. The fact that in some places successive terraces are found does not disprove the theory, because it is more than likely that when the ice receded it did so in successive stages, remaining at different positions for a considerable length of time. There is abundant proof of this in the successive moraines and also in the formation of successive terraces. Some of these terraces could have been formed from other causes.

It does not require any great stretch of the imagination to understand how numerous lakes, much [Pg 227] larger than any at the present day, may have extended over large portions of the West and Northwest during the period that the ice was receding. The ice did not stand with an even thickness over the surface of the glaciated area, but at some points it moved down in great lobes, which marked the lines of greatest pressure as well as the greatest accumulation. As the ice melted away, the thick bodies of ice might be many, many years in melting, and they might block the outlet to a very extensive drainage area and thus form a great inland sea from the vast amounts of water that would come from the melting ice.

All of the region about Winnipeg, in the Red River country, covering great areas of hundreds of miles in extent, is a level plain only lacking the coloring to give to one passing through it the effect of a great unruffled sea. There is no doubt but that all of this region was the bottom of a great lake at some period when the ice was receding. And this accounts for the great depth of black soil that we find in this and other regions. The soil was a water deposit, such as may be found in the bottom of any shallow lake or pond to-day, and thus many thousand years ago provision was made for the fertile areas which to-day are feeding the world with wheat.

We can imagine that during this period the water that flowed off through the great Mississippi [Pg 228] must have been of enormous volume as compared to the present time. A large portion of the delta of the Mississippi which now is a part of the States of Louisiana and Mississippi was carried down during the ice-melting period. Dr. Wright—as we have before stated—has estimated that there are a million square miles of country that has been covered to an average depth of fifty feet with glacial drift. A very large amount of the earth that was spread over the northern portion of the United States by leveling down hills and mountains in the northern country and scooping out the great lakes has been carried much farther than to the margin of the ice sheet. And I have no doubt but that a great portion of Louisiana and western Mississippi is made of earth carried down largely during the period of melting ice and deposited in this great delta.

Imagine the effect that would be produced by the giving way of an ice dam or a great number of them at different periods, that would allow a body of water as large or larger than Lake Michigan to be drained off in a comparatively short time. When we think of it in this light the great delta of the Mississippi is easily accounted for.

There are evidences of a great lake in the Red River country of the Northwest that is much larger [Pg 229] than any of our greatest lakes. The shores of this lake—the bed of which is now dry land and the heart of a great agricultural region—are well defined and have been surveyed and mapped out. When this great body of water was released it was to the northward. For this reason it was undoubtedly held for a much longer time than some of the lakes to the southward where the ice melted sooner.

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CHAPTER XXVIII.

SOME EFFECTS OF THE GLACIAL PERIOD.

There is a wonderfully interesting effect produced by the action of water during the subsidence of a glacier at Lucerne, Switzerland. Some years ago there was discovered under a pile of glacial drift at the edge of the town of Lucerne a number of deep holes worn in a great ledge of rocks that crop out at that point. One of these pot-holes having been discovered, excavations were continued until a large number of them were unearthed of various shapes and sizes. I had the pleasure of inspecting some of them in the year 1881. They are situated within an inclosure called the Garden of the Glaciers. Some of these holes are twenty to thirty feet in diameter, and the same depth. There are others that are smaller in size, but all of them possess the same general characteristics.

In the bottom of each one was found a bowlder, and in one or two cases two of them. The action of the water had given these bowlders a gyratory motion, which gradually wore away the rock [Pg 231] underneath until round holes were formed to the size and depth heretofore mentioned. Where there was only a single bowlder the holes were almost perfectly round, but where there was more than one bowlder the holes were sometimes in an oblong shape. The bowlders were worn down to a very small size in most cases, and were round and smooth. The probabilities are that when the action first began these bowlders were large and of irregular shape. They must have been, in order to do the enormous amount of grinding that some of them did to produce excavations in the solid rock with a diameter of thirty feet and a depth about the same. The bottoms were round like an old-fashioned pot, and the insides polished perfectly smooth. This was purely an effect of the tumbling about of the bowlders by the running water from the melting ice of the great glacier that covered that region some time in the long ago.

There are other effects produced in rocks during the ice flow in North America that are very interesting. Great grooves are formed in the rocks, in many cases running for long distances, that have been worn in by the cutting power of the great ice sheet during the progress of its movement. There is a great groove to be seen at Kelly's Island in Lake Erie. It will be remembered that this lake is supposed to have been formed entirely by the ice of the glacial [Pg 232] period. In its movement across the country which is now covered by the lake the ice encountered a huge rock formation at Kelly's Island. Great V-shaped grooves were cut through this rock by the action of the ice, deep enough for a man to stand in. In other places the rock was planed off in the form of a great molding, a number of feet wide, with the same smoothness and accuracy as though done by a machine.

Another effect of the glacial period has been the creation of numerous waterfalls throughout the glaciated area. The most notable instance is that of the Falls of Niagara.

In preglacial times the beds of all rivers and water courses had worn down to an even slope, so that there were very few, if any, waterfalls such as we have to-day. As we have before stated, Niagara River as well as the St. Lawrence River is a new outlet for the drainage of the great lakes. A part of this drainage formerly had its outlet through the Mohawk Valley into the Hudson, which is now filled up with glacial drift. The evidence is so conclusive that it is no longer doubted that the Niagara River dates from the time that the ice receded from that point. When the water first began to flow through this new channel it plunged over the high rocky cliff at Queenstown, and from that time to this it has been wearing its way back to the present position of Niagara [Pg 233] Falls, a distance of about seven miles. A vast amount of interest centers about this river because it is the best evidence we have of the time that has expired since the glacial period. A great deal of study has been given to determine the amount of erosion at the Falls during a year's time. If this could be accurately determined, then by measuring the distance from the present falls to Queenstown, we could easily determine the number of years since the ice period. It is difficult to determine, for the conditions may have changed; for instance, the rock at the Falls to-day is said to be harder than it is further down toward Queenstown. The estimates vary from 35,000 years to 10,000 years—that is, from a rate of erosion of five feet to one foot, per year.

Every science is, nearly or remotely, related to every other science. If we could determine accurately the date of the ice period it would settle a whole lot of other questions that are related to it, and one of them is the antiquity of man. Many stone implements such as were made and used by the aborigines have been found at various times buried deeply under the glacial drift. These finds have occurred so often that there no longer remains a doubt but that a race of men existed on this continent in preglacial times. There are evidences that at a time long ago the temperate zone extended far north of this, and it is not impossible that what is now the continent [Pg 234] of Asia and that of North America were joined. In fact, they come very close together to-day at Bering Strait. If such were the case this continent could have been inhabited from the old world by an overland route. This, however, is mere speculation. There are a number of factors that are taken into account in determining the period of the ice age besides the Niagara River and the Falls. The Falls of St. Anthony at Minneapolis (which like the Niagara is a creature of the ice age), the wear of water on the shores of the great lakes, the newness of the rocks that are piled up on the terminal moraines, all point to a much shorter period since the ice age than it used to be supposed, and indicate that the time does not exceed 10,000 years.

To the ordinary mind the ice age no doubt seems like a myth, but to the man of science who has made a study of all of these evidences it is as real as any fact in history, and much more real than some of the history we read. In the former case we are dealing with evidences that appeal to our senses, while in the latter we are dealing with the recollections of men concerning what purport to have been actual transactions, and we know enough about the human mind to make it difficult sometimes to draw the line between the actual and the imaginary. [Pg 235]

The glacial period is not only closely related to the topography of North America and parts of Europe in the changing of river beds, the formation of lakes, the transportation of rock, the grinding down of mountains and spreading the débris over thousands of miles in extent, but it is related in an intimate way to many of the sciences, such as botany and zoölogy. A study of the flight of animals and plants in front of the great advancing ice sheet is a subject of intense interest. The migration of great forests would seem to be an impossible thing when viewed from the standpoint of a casual observer. It is true that individual trees could not take themselves up and move forward in advance of the oncoming ice, but they could and did send their children on ahead, and when the ice had overtaken the children there were still the children's children ad infinitum.

By an examination of the map it will be seen that the land gathers about the north pole, while the south pole is surrounded chiefly by great oceans. As we have hinted before, in preglacial times the temperate zone extended much farther north than it does to-day, and north of that there was an arctic zone (which to-day is largely covered with ice sheets), where forests, plants, and animals flourished that were fitted for an arctic climate. When the glacial period set in and the ice sheet began its southern journey this zone or climate was moved southward in front of the [Pg 236] ice, thus forming, as it were, a moving zone whose climatic conditions were similar to those of the arctic regions (at least so far as temperature was concerned) in preglacial times. The ice movement was so gradual that time was given for forests to spring up in advance of it that moved southward at about the same rate as that of the moving ice. Undoubtedly the average movement was very slow and was probably thousands of years reaching its southernmost limit, which is now marked by the terminal moraine. Thus it will be seen that while the individual trees and plants could not move, the forest as a whole could. It was gradually being cut down on its northern limit and as gradually it grew up on the southern limit of the zone; the ice movement being so slow that the young tree of to-day on the southern limit becomes a full-grown king of the forest by the time the relentless icebergs reach it and cut it down and thus the process went on until the plants, trees, and animals of the arctic region were driven hundreds of miles south of the great chain of lakes on the northern boundary of the United States.

Many of the animals of preglacial times were unable to stand the strain of the ever-changing climatic conditions and have become extinct, but their fossil remains are left to tell the story to [Pg 237] the present and future ages. Much of the history of those times is a sealed book, but the persevering energy of the glacialist and archæologist is gradually turning the leaves of this old book and revealing new chapters of the wonderful story of the ice.

As the ice receded the arctic zone again traveled northward, and many animals, plants, and trees that had survived the vicissitudes of the ice age, traveled back with it. Some of them, however, became acclimated and by adapting themselves to the new conditions remained behind to live and grow with the aborigines of preglacial times. Some of the plants and flowers that grew in profusion immediately under the edge of the great ice sheet were unable to live under the new conditions of increased warmth—that came with the retrograde movement of the ice—and either had to follow closely the receding ice or escape to higher altitudes, where they found a congenial clime. Thus it is that we have arctic plants and flowers above the timber line and near the snow line of our high mountains. In proof of this theory it has been found that these arctic plants do not exist upon high mountains, such as the Peak of Teneriffe, where they have been isolated from the glaciated region. The Peak of Teneriffe is situated on one of the Canary Islands, surrounded by water, so that there was no possible chance for the arctic plants to seek refuge on these [Pg 238] isolated elevations, such as the continental mountains furnish.

Thus it will be seen that the progression and recession of the ice have not only formed great lakes, changed river beds, and covered a million square miles of area with glacial drift averaging fifty feet in depth, making many waterfalls and giving variety to the surface of the earth, besides producing the finest agricultural region in the world, but have also given variety to our forests and plants wherever this ice sheet has extended.

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CHAPTER XXIX.

DRAINAGE BEFORE THE ICE AGE.

We have already said that during the ice age river-beds were changed, valleys were filled up, new lakes were made, and waterfalls created. Great as were the changes made by the carrying power of moving ice, still greater were those made in preglacial times; not, however, from the action of moving ice, but from running water. Erosion caused by running water has, probably, during the life of the world, transported more material from place to place, from mountain to valley, and from valley to ocean, than any other agency; chiefly for the reason that it has been so much longer doing its work.

The valley of the Ohio River, a thousand miles or more in length, together with the great number of feeders that empty into it, is an instance of the wonderful erosive power of running water. The valley of the Ohio River will probably average a mile in width at its upper level and, deep as it is to-day, it was much deeper in preglacial times. There is evidence that the whole bed of the river was from 100 to 150 feet deeper than it is at present. [Pg 240] This has been determined by borings at different points to ascertain the depth of the drift that was lodged during the glacial period in the trough of the Ohio River. Anyone traveling up or down the river to-day can readily see that it is a great sinuous groove cut down through the earth by millions of years of water erosion, and not only this, but that at some time in its history this great valley has been partly filled, forming on one or both sides of the river level areas—called bottom land. These lands are exceedingly productive, owing to the great depth and richness of the soil.

For many years the writer lived upon one of the rivers tributary to the Ohio and often made trips by steamboat up and down the Ohio River. Traveling along this river a close observer will be struck by the exactness of the stratifications in the rock and in the coal beds to be seen on each side of the river. They match as perfectly as the grain of a block of wood when sawn asunder—showing that these coal beds were formed at an age long before the water cut this sinuous groove. What the water was doing while these coal beds were forming will be brought out in some future chapter. All the rivers that are tributary to the Ohio, such as the Monongahela, the Alleghany, the Muskingum, the Tennessee, the Cumberland, the Kentucky, the Wabash, the [Pg 241] Miami, the Licking, the Scioto, the Big Sandy, the Kanawha, the Hocking, and the Great Beaver, besides numerous smaller streams, have their own valleys that have been worn away by the same process, and to a greater depth than they now appear to be. All of the material that once filled these valleys has been carried down by the water filling up the bottom of the ocean and building out the great delta of the lower Mississippi. Mountains have been worn down and carried away by the action of the running water until their height is much lower than in former times. The great lakes, that were enlarged during the glacial period and in some cases wholly created—by the scooping out and damming up of the waterways and by piling glacial drift around their shores—have had some of their outlets raised to a higher level, and others have been created anew.

The old river beds that formerly carried the water that is now drained through the St. Lawrence were eroded by the action of running water to a great depth, as is shown by numerous borings along the valley of the Mohawk and down the Hudson. The salt wells at Syracuse, N. Y., have been put down through glacial drifts and the salt water is found in the bed of the old river. Great bodies of salt are found at that low level, constantly dissolved by the water percolating through [Pg 242] the sand and gravel of the glacial drift. This salt water is pumped up and evaporated, leaving the salt—forming one of the important industries of that region. All of the rivers from the Ohio eastward tell the same story, which is that at some remote period the land was much higher above the level of the sea than it is to-day. The bottoms of many of these old river beds are lower than sea-level, but as they were made by running water they must have been at one time above that point.

There is abundant evidence that the earth sinks in some places and rises in others. Along the ridges of some of the eastern mountains are found in great abundance the products of the bottom of the ocean. These evidences show that at some period, when the mountains were formed, a great convulsion of nature raised the bottom of the ocean to thousands of feet above its level. Evidences of this exist in various parts not only of the United States, but of the world.

You ask, If this erosion goes on and the mountains and hills are carried down and filled in to the low places of the ocean, what is the final destiny of the earth that now appears above the surface of the ocean? Evidently if the earth should remain without further upheaval, at some time in the far, far future the land would gradually wear down and be carried off into the ocean and the ocean would gradually rise, owing to its restricted area, until it would again cover the whole earth as it undoubtedly did at one time in the earth's history. This fact need not occasion any uneasiness on the part of those who are living to-day or for millions of years to come.

The problem of building a world and then tearing it to pieces is a very complicated one. There is a constant battle going on between the powers that build up and those that tear down; and this is as true of character-building as it is of world-building. The world has never been exactly alike any two successive days from the time its foundations were laid to the present moment. It seems to be a fundamental law of all life and growth, as well as of all decay, that there shall be a constant change. There is no such thing as rest in nature. The smallest molecules and atoms of matter are in constant agitation. In the animal and vegetable world there is a period of life and growth, and a period of decay and death; and this seems to be the destiny of planets themselves as well as the things that live and grow upon them. Still, science teaches us that with all this turmoil and change nothing either of matter or energy is lost, but that it is simply undergoing one eternal round of change. Does this law apply to mind and soul? Do we die? Or do we simply change?

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