Appletons' Home Reading Books

EDITED BY

WILLIAM T. HARRIS, A. M., LL. D.

UNITED STATES COMMISSIONER OF EDUCATION

DIVISION I

NATURAL HISTORY

Dr. JULIUS HANN,

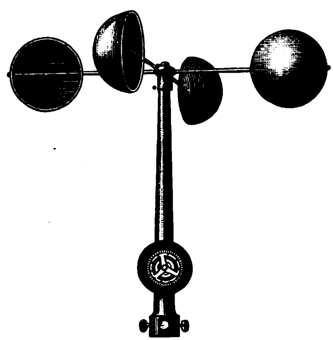
Director of the Austrian Meteorological Service.

APPLETONS' HOME READING BOOKS

ABOUT THE WEATHER

BY

MARK W. HARRINGTON



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INTRODUCTION TO THE HOME READING BOOK SERIES BY THE EDITOR.

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

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

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

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

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

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

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

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

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

The Home Reading Books are to be classed as follows:

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

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

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

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

Plan for Use as Supplementary Reading.

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

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

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

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

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

W. T. Harris.

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

PREFACE.

NOTHING a few years ago seemed to us more capricious and lawless than the weather. The winds blew where they pleased, and no one could tell whence they came or whither they went. And yet, like all other phases of nature, the weather has laws—uniform, unchanging, and inflexible—which it must and does obey.

Short as the time has been since the weather has been studied as a science, many, though by no means all, of these laws have been discovered; and a knowledge of them is, without doubt, not only of considerable interest, but of the greatest possible utility. Without dwelling upon a thousand and one pleasures that are contingent upon a correct forecast of the weather —cycling, boating, driving, and the like—the builder, the sailor, and the farmer learn that not prosperity alone but life itself sometimes depends upon ability to perceive and understand warnings given by science and nature of what is, within the next few hours, to be expected of the elements.

It is a matter of vital importance to the people who live in tracts of country traversed by the fearfully destructive cyclones that annually visit the Western parts of the United States to be able to detect the coming of one of these terrible tempests long enough to insure the safety of themselves and of their property. To do this properly requires no long apprenticeship, no great amount of arduous study of the subject. It is safe to say that within the covers of even so small and unpretending a work as the present one, written as it is by the well-known author who has made a lifelong study of the weather, everything essential to taking practical advantage of all that is now known on the topic is to be found.

The more than twelve hundred thousand dollars expended every year by the Government may perhaps be considered an exorbitant price to pay for learning what weather we are likely to have for the coming twenty-four hours; but the truth is that no public investment is so immediately and so immensely profitable as that applied to the maintenance of the Weather Bureau.

Not only are the cyclones in the West, but the floods of streams and rivers, especially those of the Mississippi Valley, are foretold, "and incalculable saving of life and property," as Mr. J. E. Prindle says in a report on the subject, "result from their warnings. Before the days of the bureau," he proceeds, "the West India hurricanes came unannounced, and sometimes two thousand lives were lost in a single storm. Under the warnings of the Weather Bureau three such storms have passed in succession without the loss of a single life, and the property destroyed in one storm would support the service for two years. At Buffalo, in the winter of 1895–'96, by forecasting six very severe storms, one hundred and fifty vessels, valued at seventeen million dollars and carrying eighteen hundred persons, were held safely in port by the warnings."

But it is useless to multiply examples of this kind; they are constantly occurring.

In the theory of education, which above all aims to be practical in selecting branches of instruction that are best fitted to be turned to account in life and experience, a study of the art of forecasting the weather must naturally hold a high place; and, indeed, in any system of education few fields of scientific investigation offer more interesting and valuable results in teaching close and discriminating observation of nature and in reasoning out and drawing logical conclusions from given premises than does this study.

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CONTEST OF MANKIND WITH THE WEATHER.

THE world outside of us, which we call Nature, may be looked on as a friend that aids us, as a tutor that teaches us and compels us to learn, or as an enemy which we must conquer. Each point of view is a true one, and each has its interest and advantages. Here it suits us a little better to take the last of the three standpoints, and look on the long progress of man toward the highest civilization as a series of struggles with the great elements of Nature.

These elements may, if not controlled, be destructive to him; may, in any case, tend to limit his activity. The contests with them give him, if he is strong, greater strength and power—physical, mental, and moral; but weaker individuals and races go to the wall in the long fight.

The struggle can be divided into seven different contests. The first is that against the inclemencies of weather and climate, in which man sets up his defenses in the shape of fixed shelter or buildings, and portable ones, or garments. This contest, and the weather against which it is made, form the subject of this book, and later will be discussed in full.

The second contest is that with the soil and the rocks, and its success means agriculture and mining. It is the first decided step of man above the beasts, for they, as well as he, have to fight the weather; but they do not attempt the cultivation of the earth, nor the digging up of metals. In this struggle man not only subdues the soil, but selects wild plants, and by cultivation and care makes them yield him a hundredfold more than they would in the wild state. Thus he subdues wheat, cotton, the apple, orange, banana, and the grape. In some cases, as the banana, the plant has been so changed as to no longer even produce seed, but depends solely on man for its continued existence on the earth.

The third is the contest of animals; and this means, not only the mastery of dangerous wild animals, but the conquest of several kinds by domestication, whereby they become the friends and slaves of man. Some have been so completely subdued that they can no longer sustain themselves in the wild state, or without man's help. They have also been so changed that the ancestral forms in most cases can no longer be recognized. This is the step that more than all else shows man's complete mastery of the brutes. In the end the most of the species of the lower animals will disappear.

Fourth, man's conquest of the forest affords material for a large percentage of his manufactures. Fifth, he attempts to subdue the forces of Nature, and having made an obedient slave of that powerful and heartless monster, steam, he is now going to put a harness on the lightning, making it replace the horse on the street and the lamp in the house.

These, by the establishment of routes for the use of travel, commerce, and the collection and distribution of news, make the great task of conquering time and space easier. This sixth is one of the greatest of man's conquests over Nature, and it is going on now before our very eyes. We are at the same time entering upon a very disagreeable contest, the seventh, of which we have lately learned the true character. It is that with the germs of disease. The diseases we have known for ages, but we have only lately learned what makes them. These germs of disease are very unpleasant to deal with, not only because they are the causes of disease, but also because they are creatures of filth. They are also creatures of weather and climate, and must be referred to from time to time, later. Here they serve to bring us back to the weather, which is our proper topic, and from which we strayed to show its relations to other things.

The greatest, most far-reaching, and most enduring of all these struggles of mankind is that with the weather. It begins as soon as man begins, and will continue as long as man continues. Man constantly succeeds in this contest, and as constantly finds that the success in the last battle is not the end of the war.

He evades the rain by erecting a temporary or permanent roof, or he escapes the cold by taking refuge in a cave or building a fire. But when he has done this he finds the work still incomplete. His roof is not yet sufficiently perfect to meet his ever-new demands, and he occupies himself for centuries in improving it, reaching at last the almost perfect form of overlapping slates. The cave of the primeval man is too dark or too open, his fire too hot or too cold. Everything needs adjustment, and again new adjustment, to changed conditions or to changes in himself. And when he has obtained shelter for himself

FIG. 1.—An Omaha dwelling, a rude protection against the weather.

and his family, he must have it for his animals, his business, also his commerce, his mails, and so on. So the adjustment goes—always advancing, never quite completed.

In the course of the contest man finds much to compensate him for the labor and danger he has undergone. The first result is his dwelling (Fig. 1) or house, and to this is due all

FIG. 2.—Japanese cooly's hat and straw coat, good protectors against, first the sun, second the rain.

those domestic and legal relations which good old-fashioned English sums up in the word "home." From these relations, we are told, are derived the fundamental principles of society (Fig. 2).

Another result of the weather contest and the creation of the dwelling is that great concentration of mankind, that enormous aggregation of men, which we call a city. An ordinary tenement house has the population of the ordinary small village or hamlet, and one of the modern lofty office buildings has a daytime population still greater. These things are possible only when the shelter contest has created an advance toward perfect dwellings.

The mechanic arts receive their chief stimulus from the necessity of protection against the weather. They are fully involved in the structure of dwellings, and in providing all those innumerable requirements of our civilization, such as sewers, light, heat, and water. Convenience, comfort, and luxury must be equally consulted, and the mechanic arts are the servants of each.

To this struggle, too, belongs the development of the fine arts. All these require protection from the weather except landscape gardening and, to a less degree, sculpture and architecture. Books and leisure, and hence learning, are indebted to this contest, and so are the majority of the refinements, delicacies, and elegances of life.

But the chief advantage in the long struggle is not so much in what man has done as in what it has made of him. The fight has given him a high degree of training, and developed the brighter and more success-compelling side of his character, giving courage, confidence, self-reliance, and industry—a most worthy quartette, all of the highest value. The moral training that comes from this conquest is also great, for as a result of satisfying his social instincts in living together in communities, man becomes, and must continue to be, honest to be safe, honorable to be respected, forgiving to be forgiven, and mild if his life is to be peaceful or even tolerable.

CHAPTER II.

THE WEATHER CONQUEST NOT AN UNMIXED BENEFIT.

The protection of man from the weather, like all other conquests and successes, is made only at some cost, and is not without its drawbacks. It is important that the true nature of these should be understood. They are of five different kinds.

The first is the artificial sensitiveness or lack of tone which is introduced by the civilized habit of carefully protecting one's self. The savage is free from this. The natives of Tierra del Fuego endure a climate something like that of Sitka or Juneau, yet live in boats or imperfectly constructed huts, and have only very scanty clothing, often nothing more than the skin of some wild animal about the loins. To them a change of temperature, that would be very trying to us, is not serious, and they suffer only in extreme weather. Exposure to the weather during their entire lives has taken away the sensitiveness which we, for many successive generations, have cultivated.

The same thing is shown to a degree by the hand and foot. We accustom the hand to remain generally uncovered, while the foot is kept clothed. The result is that the hand will bear without inconvenience an exposure that to the foot causes suffering.

The protection our houses and garments afford us is often more than sufficient. We can live, for instance, in perfect comfort in a house kept heated to 60° in winter, but many tenants heat their houses to 70° or even higher. The latter become highly sensitive to the cold and suffer more when they go out into the open air.

The remedy lies in accustoming one's self to living in cool rooms, to wearing light clothing, and especially to having light bedclothing. This sensitiveness and lack of tone are probably acquired in the bed chamber more than elsewhere. Light bedclothing and open windows in the sleeping room will go far toward remedying the trouble, and will, besides, give the freshness of mind and body which results in cheerfulness, and in clearness of skin which is a great part of beauty.

When this sensitiveness is excessive it results in a series of dangerous diseases. Though comfortable and protected at home, we have to go out into the open air from time to time, and when the weather is bad, whether very hot or very cold, very wet or very dry, the sudden new and sharp impression on the skin may have serious consequences.

The least dangerous result is what we call a cold. The blood driven suddenly away from the surface by cold or damp is likely to accumulate in too great a degree on the mucous surfaces inside the body, and an inflammation ensues. If this goes on it may lead to pneumonia, pleurisy, or some similar disease, with great and immediate danger to life, or it may so weaken and undermine the tone of the mucous surfaces that they easily contract other diseases.

The remedy is the same as in the previous case. It is necessary for those who wish to be vigorous and healthy to avoid coddling; that should be left to genuine invalids, and they should have as little of it as possible.

A second result of our seclusion from the weather is neglect of physical activity. The pursuits of modern society run to the intellectual and neglect the physical side of our nature. The result is the loss of physical strength and a general laxity of the body, causing muscular weakness, besides giving rise to obesity greatly injuring physical beauty.

This has grown so serious that recently a reform—modern gymnastics—has been introduced to correct the evil. The ancient Greeks practiced gymnastics mainly for beauty, and the ancient Romans for strength. They lived much more in the open air than we do. We have introduced gymnastics chiefly to remedy the bad results of too much confinement, but even with the limited use we make of systematic exercise the effect in increase of beauty and strength is noteworthy.

The third result of man's protection from the weather is the accumulation about him of the poisonous products of his own life. Whatever a living body rejects because it is through with it, is poison if taken into the body again. In natural surroundings these things are scattered and diffused until they are innocuous, but in the compact and closed space of a modern dwelling they are as much prevented from being dissipated as is the heat; and this state of things is still worse in a city where the dwellings themselves are crowded—so crowded that a single building may contain many different dwellings, each occupied by a separate family.

Now, the accumulation of poison most likely to occur is that of carbonic-acid gas, for it is not only given off by the breath, but also by the fires and the flames of the candle, lamp, and gas jet. And this gas is still more likely to accumulate in public halls where many people come together. It suffocates by cutting off the supply of wholesome air, and it also poisons; when abundant, it proves fatal in a few hours.

The poisonous gas next most likely to accumulate is that from the sewers in a city. It is an indirect product of all the excretions and other substances, mainly products of decay, carried off by the sewers, and is so lacking in odor that it can not be recognized by its smell. It is sure to come into a city house which has been unoccupied, where the traps have been neglected. It is more poisonous than carbonic-acid gas.

The remedy for these dangers, due to the very completeness of modern dwellings, is in ventilation; but this is the one feature of our buildings which has not yet been perfected to a point of genuine safety. Ventilation is difficult to manage in winter without great loss of heat and expense in fuel. The best ventilator of all is an open fireplace, but it is the very form of heating which is most wasteful and extravagant.

The fourth and worst result of protection from the weather is the opportunity it gives for the development of seeds of deadly diseases. In a natural condition these seeds or germs are developed in relatively small numbers, have little strength to injure, and are so blown about by the wind that they do little damage. Moreover, the rays of the sun usually destroy them; and in the open air under the sky they find few secure places of refuge. They are, when exposed to the open air, dangerous only in the heat of the tropics and in certain damp, dark, and swampy places in the temperate zones.

These little invisible fragments of life are especially fond of filth, where they grow much better than in clean places. When they find filth, heat, and darkness all together, they multiply at an amazing rate, and at the same time become malignant. All these they find in certain tropical cities, as Canton and Bombay, and there they sometimes become so deadly that the very rats, that usually live and thrive on filth, sicken and die in great numbers.

Such conditions sometimes occur in neglected spots in all cities and in unclean houses, and these may become centers from which pour out multitudes of the minute, death-carrying germs. The only remedy is cleanliness; and cleanliness on a large scale is called sanitation. The sanitary officers of a great city, in insisting on a high degree of cleanliness everywhere, do an amount of good which can hardly be overestimated.

When germs of disease have found a suitable home and have begun to spread, they may be carried about in the clothing or in the baggage of travelers, and especially in the bodies of those already diseased. Then another remedy has to be set up; for it is not only necessary to be clean one's self, but to avoid contamination by others. It is curious to think of men patroling the boundary of a country with guns in their hands to keep out an army of minute, invisible germs; but this is often successfully done.

The last of the drawbacks to our conquest of the weather to which we shall refer, is perhaps the most painful of all. In his conquest man has developed luxury, and made a large number of needless things absolutely necessary and indispensable. To a savage the number of things which he must have probably does not number twenty, and to the Tierra del Fuegian or the black fellow of Australia may not number half a dozen. To the writer of this they number at least five hundred, and to the reader perhaps more. Let him count them and see. An Indian travels with almost nothing except his horse, garments, and weapons; a modern belle travels with huge trunkfuls, and these are all necessities to her.

The development of the needs of modern life, due largely to the weather conquest, has made more money necessary, and this makes poverty more difficult to avoid and more common. What feeds an Arab abundantly is starving provision for one of us. The pressure of poverty causes not only unhappiness, but is a fertile source of crime. The remedies for poverty and crime are found in philanthropy and law. They are not at all to be sought for in the idea of some visionaries, that we may return to the simplicity of the savage.

Man has become civilized to stay civilized, and to grow more so. The burdens of needs which civilization causes can not be laid down, but will grow. The readjustment is not in going into the woods and living in a cave, but in the development of society, and chiefly in philanthropy. Then this very evil brings about a good in that it gives greater opportunity to the generous and noble-minded.

CHAPTER III.

THE INCOMPLETENESS OF THE WEATHER CONQUEST.

THE struggle with the weather not only has its bad results, but it is still incomplete. No sooner do we perfect one means of protection than our requirements change and a readjustment is necessary. A protection from the ordinary weather is not sufficient for the extraordinary. Some years ago a prominent Eastern engineer was called to a new Western city to devise a system of sewers. "What is your largest rainfall per hour?" he asked. "A third of an inch," was the answer. To be quite safe, the engineer constructed the sewers to carry off a rainfall twice as heavy. But hardly were the sewers completed when still heavier rainfalls than those provided for occurred, and that city has still to submit to occasional overflows of the streets from rainfalls greater than those for which the sewers were constructed. Similar miscalculations are sometimes found in the plumbing in our houses and in many other ways.

Weather for which we are not prepared is met with oftenest by persons engaged in open-air pursuits. The farmer feels this with especial bitterness. There is hardly a variation from average weather which is not injurious to him, for nearly all that he has lies exposed to the weather. Now it is the unexpected summer shower which destroys his hay; again, it is a capful of wind that lays down his best wheat and oats until it so increases the cost of harvesting that his profits disappear; an untimely frost, or drought, or rain, or snow, or wind may destroy a large part of his season's work.

The stock grower is hardly less fortunate. In the geological strata of the Western plains are found what are called bone beds—places where there are enormous accumulations of fossil bones. From them geologists have been able to reconstruct curious animals which used to live there in numbers, but have died out ages ago. These beds are where the animals were huddled together and killed by severe storms. The same kinds of storms still occur there, and they are as deadly, but now it is the cattle, horses, and sheep of the stockman that suffer.

The danger to sailors of severe weather is well known, but experience proves that some forms of extreme weather are nearly as dangerous to those who use steam as to those who use sails. Probably steam navigation is the safest way of traveling; but it has its perils, due to heavy winds and heavy seas, and especially to heavy fogs.

Still more sensitive to weather changes is the art of transportation by land, which has had such enormous development almost within the memory of many who yet live. Since 1805 the number of miles of railway has grown from nothing to about half a million miles; enough to make a double steel band from pole to pole forty times over, and to give employment to perhaps five millions of people. The street-railway development is later and even more remarkable. This enormous network makes the very arteries and veins of the world's land business, and any interruption to it is felt within a few hours in every home, except the most isolated or the savage ones.

This modern business called transportation is especially liable to injury by the weather, both because it is carried on beneath the sky and because, being new, it has not yet completely adjusted itself to the conditions under which it exists. Floods carrying away its bridges and culverts, interrupt its business; heats dry up its wooden structures and lead to their burning; thaws bring avalanches of snow and earth on its track, and even a fall of snow of very moderate character may delay, or for a time, interrupt traffic.

In addition to all this there is always a possible series of injuries to its freight by frosts or unusual heats. Indeed, it is not easy to protect large boxes on wheels, flying along at twenty miles an hour or more, against the weather.

A very curious modern development is that of trade in information, for commercial and journalistic purposes. This involves the wires and poles of the telegraph and telephone companies, and the business is especially sensitive to the weather. Even the electric condition, that part of the weather which is most obscure, is here of great importance.

Another of the great interests of man especially subject to weather changes, though in limited directions, is the system of streets of a great city. The relation of the rainfall to the sewers has already been mentioned. The rain also produces mud on the street, which must be removed as soon as possible; a heavy fall of snow calls out an army of men and horses to clear away this great obstruction to traffic. The actual care of the streets of Boston for the first fortnight in February, 1898, cost eighty-eight thousand dollars, and to clean the snow from all the streets of New York city it is estimated would take two millions of dollars per year.

These figures give some conception of the money interests involved. The remedies employed and attempted are numerous and elaborate. They will be noticed in the succeeding chapters.

CHAPTER IV.

REMEDIES FOR INJURIES BY WEATHER.

REMEDIES for the injuries inflicted upon man by extremes of weather have been actively and earnestly sought in all directions. Attempts have been made to predict the weather accurately, to try to solve the complete weather problem, and even to try to make weather. The remedies are undertakings which, when successful, bring a great compensation with them. The person who invents a device or discovers a way to save the railway companies a cent a mile per train, or the farmer a cent a month per acre, will be rewarded by a fortune.

To illustrate, let us take that newest of arts, the use of electricity. It suffers from weather exposure in many ways. The poles and wires are especially liable to be struck by lightning out on open plains or when crossing bare mountains. Sometimes the lightning spreads along the wire and shatters a dozen or a score of posts on either side of the road.

The apparatus for conducting man's tamed lightning needs especial protection from the wild lightning of Nature, and a series of special lightning conductors and lightning arresters have been devised.

In some cases the lightning is taken up without discharge by the wires and conducted to the receiving instruments in the offices, where it may only glow and supply a surplus which replaces the comparatively feeble currents made by man, and in this way interrupt business; or it may make discharges which are dangerous to the operators, or which burn out the instruments, and perhaps set fire to the building. The danger at the receiving instruments is repeated wherever there is a break or a weak point in the wires. To remedy these dangers, lightning arresters and other devices are used; they are only partially effective.

If the state of the atmosphere is foggy or rainy, or even very moist, the insulation becomes incomplete, and the electric current leaks away to the ground, causing interruption of business and danger to life and property where the leakage occurs. Special devices for insulation are required to avoid this, and they are of varied character. These are all cases of overcharge or loss to the current.

Another series of weather extremes brings the wires to the ground. For instance, in cer-

FIG. 3.—Accumulation of hoarfrost on Mount Washington in winter.

(*From a photograph published by Kilburn and Company, Littleton, N. H. Loaned by the Weather Bureau.*)

tain exposed situations, as in mountain passes, hoarfrost forms to an enormous amount, becoming sometimes a foot thick on all stationary objects. This breaks down the wires. Ice storms load the wires with a similar result. No satisfactory remedy for these dangers has been found. They are not common, but, so far, admit of no remedy. They can be repaired only after the damage has been done.

There is also a series of damages to which the poles are exposed. Lightning may shatter them; floods may carry them away; landslides may overwhelm them, and snowslides among mountains are quite as damaging in the spring or during warm storms. To remedy these dangers, wires have been put underground, but there a new series of leakages and breaks occur, and it is difficult to get at the wires to remedy accidents.

These details have been given at some length to illustrate how dependent upon the weather and how subject to damage by it, is the practice of that new art, applied electricity. There are also many injuries to which the practice of modern arts and industries, carried on in the open air, are subject, for which no complete remedy has yet been found.

The air, soft as it is, offers resistance to anything moving in it. This resistance, when the motion is slow, is very slight, and we hardly feel it when walking; if we run it becomes noticeable, and in rapid motion on a bicycle it is the most serious difficulty to overcome.

Calculation and experiment have shown that to anything moving at the rate of twenty miles an hour—and this is a common rate of speed on railway trains, and not very hard to reach on bicycles—the air offers a resistance of two pounds avoirdupois to every square foot of surface exposed to it; that is, it takes a push of two pounds to every square foot to force the air out of the way when we are moving at the rate of twenty miles an hour. This resistance increases rapidly as the speed increases; in fact, as the square of the velocity. If the rate is forty miles (*two* times the first mentioned), the resistance is *four* times that of the first instance, or eight pounds to the square foot; and if it is sixty (*three* times twenty) miles per hour, the resistance is *nine* times two pounds, or eighteen pounds, per square foot. If a train moves at the rate of a hundred miles an hour, as they promise it shall on certain new forms of electric railways made especially for speed, the pressure will be fifty pounds per square foot.

The adult human body, taking clothing into account, presents a front surface of about five square feet; were it not that it is rounded and that eddies occur behind it, it would have to support a pressure of ninety pounds when carried in an erect posture—for instance, on a flat car at sixty miles an hour. An ordinary train has a frontage of several hundred square feet directed forward against the air, and but for the eddies it would have to add enormously to its pull to overcome the resistance of the atmosphere through which it moves. As it is, the power required to push against the air soon becomes equal to that needed to take the train forward. Probably this occurs at a speed of about fifty miles an hour.

The resistance is lessened when the pressure decreases, as when a low-pressure storm is coming on, or when the train is at high altitudes, but the resistance of the still air to a train moving through it is the same as that offered by a wind moving against it. A high head-wind causes a great increase of work to a locomotive, and thus a great loss of fuel.

This could be remedied in part by changing the form of the surfaces of the train that are directed forward. The locomotive should be so made as to split the air. The only improvement thus far introduced is the vestibule between passenger coaches. This takes away

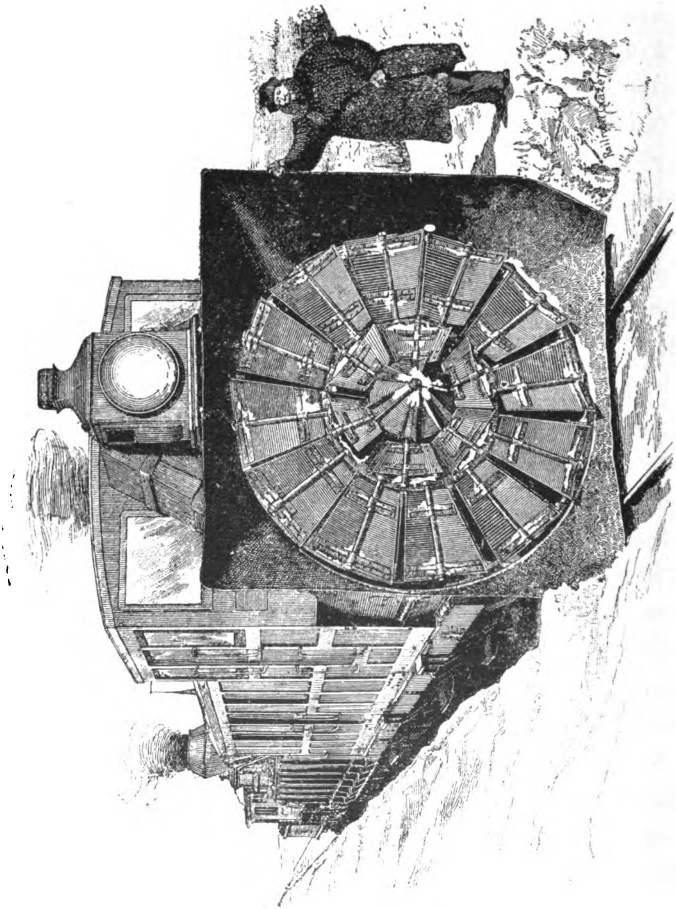


FIG. 4.—A remedy against the weather. A locomotive snowplow.

(*By permission of the Railroad Gazette.*)

the pressure on the heads of the individual coaches, except the forward one, and so greatly decreases the resistance.

Another illustration of modern remedies against the weather is to be found in the devices to prevent snow from falling on railway tracks, or to remove it when it has once fallen. Sometimes the track is covered with great unsightly sheds, miles long, especially in mountain regions where the snow is likely to be very deep. On open places, over which the wind has a great sweep, snow fences are erected in such a way as to take advantage of the eddies and make the wind itself keep the track clear.

When neither of these is practicable, snow-plows placed in front of a locomotive are used. Plunging through the snow at a high rate of speed, they throw it, when light, far away on each side. Snow brooms, used for the same purpose on street-car lines, have to be kept running during the entire storm. When the snow is heavy and wet and packs, and especially when it freezes, the road may be blocked until an army of men has been set to work to clear it away, and they may have to work at it with pick and blast as if it were so much rock.

Fogs, which cause such a dangerous delay to shipping, are remedied to some degree by fog bells or fog horns, but the sounds from these instruments do not reach far, and they also are curiously ineffective in spots even within the area where the sound ought to reach. There are places of sound shadow, due sometimes to rocks and islands, and sometimes to other causes not yet known. There are patches within easy reach of the bell or horn where no sound can be heard, and these, it appears, may be differently located at different times. These areas of silence seem to be due to the fog itself, and they are especially dangerous, for the seaman naturally thinks that if he does not hear the sound it is because he is too far away. A remedy for fog will probably be found in the telephone, for it has been proved that the water itself may take the place of a wire in conveying sounds.

Artificial weather is made in our houses and other buildings, and especially in hot-houses and refrigerators, and the attempt has been made to produce rain by artificial means. The best-known instance of this is that of Mr. Dyrenforth, who experimented with explosions for the purpose, with money furnished by Congress. He carried on his observations near Washington city and in Texas, but was not able to make rain. It is difficult enough, and expensive enough, to make better weather in our dwellings, without attempting to make it for all outdoors. No one has yet proved that explosions will bring rain; but if that were proved, it can hardly be believed that man's puny cannon, whose sound, even, reaches but a few miles, could cause rain over a State, or even over a county.

The best and most complete precaution against the weather can be found in predicting it beforehand, thus forewarning those likely to suffer from it. This has been done in various ways and with varying success. Prediction by weather signs is successful in experienced hands for at least a few hours ahead. The barometer is the best guide that has been discovered for such predictions, and the clouds next best. The weather map is a great improvement on the tabular reports, for it presents a view of the weather for the same moment over an entire country, and so permits prediction for a day or two ahead. This is the method used by the Weather Bureau. Attempts have been made by special methods to extend the predictions to a much longer time ahead—for a month, a season, or longer—but these promise little success.

We shall show the weather-map method at some length, but first we shall have to know about the elements of the weather and their combinations into storms, and modifications by the season and the lay of the land. The succeeding chapters will be devoted to these subjects.

The late development of wireless telegraphy promises to be the most efficient aid yet discovered to weather prediction.

Electric waves have been known experimentally since 1886, but their use in sending messages is much more recent. Apparatus has been devised for developing these waves in great intensity, so that they can be made efficient in carrying messages for distances as great as twenty miles, and perhaps much more.

By the use of fixed signal stations perfect communication can be maintained with parts of the earth and ocean where the use of wires is not practicable; and as neither fog nor storm nor masses of earth or rock interfere materially with the electrical impulses, it is evident that no more perfect method of sending weather reports can well be imagined.

CHAPTER V.

THE PRESSURE OF THE AIR AND HOW IT IS MEASURED.

LIKE all material things on the earth, the air has weight, which, though small, is appreciable. It takes seven or eight hundred gallons of it to balance one gallon of water. It is lighter when warm, for, like other things, it expands with increase in temperature. It is also lighter when moist, for a given amount of the vapor of water weighs but little more than half as much as an equal quantity of dry air. Air also decreases in weight in ratio of its release from pressure, as when in an air pump or in the upper regions of the atmosphere.

In ordinary weather the weight of a cubic foot of air is from five hundred to six hundred grains, the lesser value when the temperature is higher. In an ordinary room, heated to seventy degrees and kept moist, the weight of the inclosed air is five hundred and twenty grains to each cubic foot. In a room twenty feet square and ten feet high this gives a total weight of two hundred and ninety-seven pounds avoirdupois for the air—equal to thirty-seven gallons, or fourteen pailfuls of water, or nearly three gallons of mercury. The weight is divided among the gases of the air very unequally. There would be in this room of twenty feet square two hundred and thirty-one pounds of nitrogen, sixty-one of oxygen, and four pounds of the vapor of water. The last when condensed makes two quarts of water.

The pressure from anything depends on its weight and the mobility of its particles. In the case of solids it is only the pressure downward that we feel, but in a liquid or gas the pressure is exerted equally in every direction. A gas, like the air, creeps through the finest crevices, and wherever it goes it takes the pressure with it. It passes through holes so small that it is not easy to make anything air-tight, and the full pressure of the air is conveyed through a keyhole or through a pinhole as effectively as in the open air under the sky.

We are at the bottom of the ocean of air, and so get the weight of all of it that is directly above us. The air is several hundred miles deep, and a column of this length is pressing upon us, pressing not only downwards but at the sides and upwards. Although the air is light in itself this is enough to give a heavy weight. It is measured by making it balance a weight in vacuum, and this is most easily done with the mercurial barometer when a closed glass tube preserves a vacuum above the mercury.

In this way it is found that the pressure of the air at sea-level is nearly fifteen pounds on each square inch. This means that on each square inch of everything—the floor, the walls, the ceiling, an eggshell, a glass bottle, the surface of animals and plants, however delicate they may be—there is a pressure equal to the weight of a gallon and a half of water or that of a peck of wheat. On each square foot the pressure is more than a ton! On the floor of the room twenty feet square, mentioned above, there is an air pressure of 400 tons, on the ceiling the same, and 800 tons on the walls, making 1,600 tons in all, or, to be exact, 1,728.

The natural question arises, why all things, except the most solid ones, are not crushed by this enormous pressure? They would be were it not for the fact that the pressure is equal on all sides. The pressure downward upon the floor is counterbalanced by an equal pressure upward, and that upward upon the ceiling by an equal one downward. If the air is removed from one side this pressure very plainly manifests itself. For instance, in the old-fashioned way of bleeding people a process called cupping was used, which made the pressure of the air aid in causing a flow of the blood. A bit of paper was set fire to, placed in a little glass beaker, and this was clapped on the fleshy part of the arm and pressed down. The paper burned for a moment without injury to the patient, and in burning used up a part of the air. The air under the beaker was then less than that on the outside, and the pressure forced, or the suction drew, the flesh up into the glass dish, and the blood out of the little wound which the physician had made in it. Indeed, all suction depends on this pressure of the air. When a pump works it draws out the air which is prevented from returning by the valves. The column of water is then forced up into the pump by the pressure of the air on the surface of water supply below.

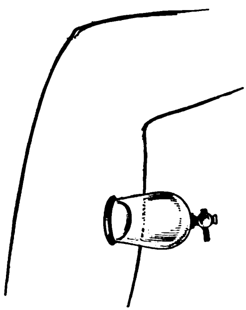


FIG. 5.—Illustration of the suction effect of air pressure in the old-fashioned cupping practiced by doctors.

The pressure of the air can be seen at work in a great many ways. The suction pump just mentioned calls it into action. The pressure of the air is enough to balance a column of water thirty-four feet high, and a suction pump will work to this height and no higher. The siphon and the air-brakes of the railway coaches also use the pressure of the air.

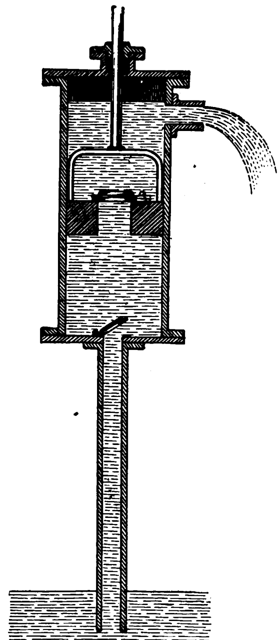


FIG. 6.—Pump.

The air is pumped out from a series of tubes in the engine so arranged that this air will then operate to press the brake shoes against the car wheels.

A very pretty experiment can be used to show air pressure. Fill a tumbler evenly full of water, and then press over the top a square of writing or blotting paper. Press the latter down lightly, but evenly, until it is in close contact with the surface of water and the edge of the tumbler. Then placing the palm of your hand over the top of the glass, reverse quickly, take away your hand, and the air pressing on the paper will keep the water in the tumbler. The paper prevents the air from rushing in to take the place of the water.

FIG. 7.—Illustration of air pressure upwards. Inverted tumbler of water kept from emptying by a piece of paper.

Air pressure is most easily measured by a mercurial barometer. This is a column of mercury in a glass tube closed above but opening below in a small basin of mercury. The column is supported by the pressure of the air on the surface of mercury in the basin. Observations are made by measuring the distance between the surface of the mercury and the top of the tube. At sea level the height is about thirty inches. The mercury changes its dimensions a little with changes in temperature, and for this a small correction must be made.

Any liquid can be used in making a barometer, but the others require longer tubes than the mercurial one; besides, most liquids evaporate readily, thus changing the height of the liquid column, destroying the vacuum, and altering the instrument. Mercury at ordinary temperatures evaporates but very little.

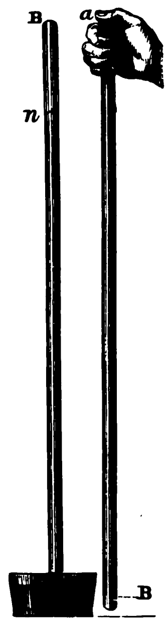


FIG. 8.—The mercurial barometer. The glass tube held on the right hand is closed at *B*. It is reversed in a basin of mercury on the left hand and the mercury in the tube falls to *n*, at which point it is sustained by the pressure of the air on the surface of the mercury in the basin. The space above *n* is a vacuum.

Another form of the barometer, and a favorite one because of its handiness, strength, and because it is easily carried, is the aneroid. An aneroid is made by emptying of air a drum-shaped steel box the heads of which are thin enough to yield a little with increase of air pressure. The motions of the heads can be made to move a hand which marks the amount of change. These instruments are quite sensitive, and large ones show very minute variations of air pressure, but they change too much with changes of temperature to be satisfactory for very accurate observations. The box is under a high strain at all times, and the thinner drumheads gradually change under this strain, until the instrument ceases to work satisfactorily.

The pressure of the air is usually expressed in terms of the height of the column of mercury which it sustains. In English this is given in inches, but in other languages it is usually given in millimetres. On maps and diagrams lines called isobars are drawn through places having the same air pressure.

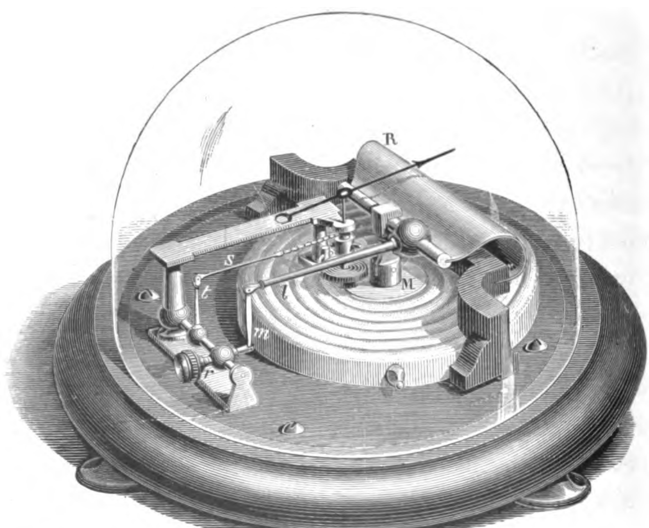


FIG. 9.—The aneroid barometer. *M* is the corrugated vacuum box. The rest consists of appliances for transmitting its changes to the arrow or pointer.

CHAPTER VI.

CHANGES IN THE PRESSURE OF THE AIR.

THE pressure of the air is neither uniform nor stationary, but it is different in different places and changes in all sorts of ways. The pressure given in the preceding chapter is, on the average, that for the northern United States at or near sea level.

In the first place it decreases as we ascend. At the level of the sea the whole weight of the air above our heads is pressing upon us, but up a thousand feet higher there is much less air above us, and consequently much less pressure. The change would be uniform if the air were not elastic, but its elasticity is very great. It yields readily to pressure, and the result is that the lower layers are condensed, and the most of the air is in the lower layers, where man makes his home. Although the atmosphere is four hundred and fifty or five hundred miles deep, fully half the air is in the first three and a half miles, and three quarters in the first six miles. The difference is very plain, as may be seen in the barometer, at Chicago. Nearly a fifth of the air is below the top of Mt. Washington. At Santa Fé, New Mexico, or in the City of Mexico, the inhabitants have air to breathe that is less than four fifths as dense as it is at the sea level. At Leadville (the highest city in the United States) fully one third of the air is below, and on the top of Pike's Peak nearly one half. In the highest ascent which man has made in a balloon the barometer went down to seven inches, and more than three quarters of the air was below. This was at about seven miles above the sea.

At an elevation of eight thousand two hundred feet, about one quarter of the air is below, one half at eighteen thousand feet, and three quarters at thirty-one thousand two hundred feet. Beginning at the sea level the barometer falls at the rate of an inch for each thousand feet of elevation, but higher up the change grows slower. In drawing isobars on a map a change is made to have them all reduced to sea level. This is done by adding to the reading for any station about one inch for every thousand feet of elevation.

There is also a slight difference for different places at sea level. The barometer is lowest along the equator, and highest in the middle latitudes. It decreases again toward the poles, but is not so low there as at the equator.

The pressure on the whole tends to be both highest and lowest over the great oceans. There is an area of high pressure on the Atlantic Ocean, in the region of the Sargasso Sea, between the Madeira Islands and the Bermudas. It changes its place back and forth in the year, being about mid ocean and farther south in winter, and near the Azores in summer. There is a similar one in the South Atlantic. Over the Pacific Ocean there is a corresponding pair of areas, but they hug the American coast more closely than do the permanent centers of high pressure over the Atlantic. The Indian Ocean has a single center of this sort about midway between Australia and the Cape of Good Hope. These permanent centers of high pressure seem to play an important part in guiding the paths of traveling storms. Such storms generally travel along the margin of these areas and on the side toward the poles, being on the north side in the northern hemisphere, and on the south side in the southern. The great storms which start on the equatorial side of these centers are more intense and destructive than any others. Fortunately, they are few in number.

The pressure also changes a little each day of the year. The change is not great; it consists of a little wave of pressure, the crest of which precedes noon and midnight by about two hours. The hollow of the wave passes at about four o'clock in the morning and afternoon. The wave is a small one, rarely surpassing an eighth of an inch in height, and decreases from the equator to the pole. It is so very regular that in the tropics it will almost serve to set clocks by. It is probably due to the great changes of temperature produced daily by the sun. It is less in the cold seasons and in cold climates.

There is also a change of pressure with the season. The air pressure is greater in winter and less in summer. Over great continents this difference is very noticeable, and, especially when the climate is dry, a winter center of high pressure is likely to form over the continent. This is not very noticeable over North America, but over Asia it produces a great center which gives the highest winter pressures on the globe. A smaller center of this sort is formed over the desert regions of South Africa.

On the other hand, there are three centers of low pressure formed on the northern hemisphere which continue in the same place, or nearly so, during the season. Those of most interest to us are over the North Atlantic and Pacific. The first lies between Iceland and Cape Farewell, and it is toward it that the storms direct their course after leaving the United States. The storms usually pass along the southern border of the last-mentioned center and disappear to the eastward of it. The second center lies along the Aleutian Islands, and is not so intense as the first. It is from its direction that a great many of our storms come, and toward it go the Japanese storms.

These centers belong to the cold or stormy season. During the warm season one such standing center of low pressure forms over southern Asia. It controls the summer monsoons so important to that continent.

The pressure also changes with the weather, and its changes are the best guides to the latter. When air rises it presses downward with less weight, and the barometer is then lower. In the same way when air descends the pressure due to its motion is added to the ordinary pressure, and the barometer is higher. The air rises in the general storms, and in some, if not all, of the local ones, and it falls in clear and calm weather. So a lower barometer is found in stormy weather and a high barometer when it is clear and calm.

The cooling of the air by expansion is very important, because the making of clouds chiefly depends upon it. Air rises, and as it gets into the higher regions it is in some measure relieved of pressure. It then expands and cools, and its moisture is in part condensed, making clouds.

We bear without discomfort the enormous pressure of the air; so completely balanced is it that we feel it no more than does the scale pan of a balance feel the pressure on its upper and lower sides. The healthy human body is not sensitive to changes of pressure unless they are very great. Variations of the weather frequently introduce, rather slowly to be sure, changes of from a thirtieth to a fifteenth of the entire air pressure—but our sensations tell us nothing of it. We can travel from the seaboard to Leadville in three days and rid ourselves of two fifths of the air pressure and yet not be conscious of it unless we engage in severe exertion, such as running or climbing. If we ride to the top of Pike's Peak or Mont Blanc there will be little discomfort, though the air is scarcely more than half as dense as at sea level. The so-called mountain sickness is due rather to severe and unusual exertion than to changes in air pressure alone. It remains to be said, however, that any great or sudden change is dangerous to persons whose lungs are not sound, because the blood vessels of the lungs are rendered tender by disease and may burst.

The lighter air of mountain tops causes the healthy to breathe more deeply. The lungs can expand very much more than they do at lower levels. There is a limit to this expansion, however, and when we pass this, suffering ensues It comes on at different elevations for different people, but in general at an elevation more than twenty thousand feet the air would be so thin as to bring on distress. Glaisher, who ascended in a balloon to thirty-seven thousand feet, when the barometer registered only seven inches, was greatly distressed and fainted away.

CHAPTER VII.

THE WINDS: THEIR KINDS AND DISTRIBUTION.

WIND is due to the tendency of the air to equalize its pressure. When the pressure at any place is less than that around it, the air flows in to make the pressure uniform. As the air is always flowing here and there in its disposition to equalize the pressure and bring the atmosphere to a uniform and quiet state, one might expect that it would at last succeed and everything become calm. And entire freedom from disturbance would without doubt come to pass were it not for the heat which the sun pours out on the earth. This is not distributed uniformly as to time or place, for it comes in the daytime only, and is less in the higher latitudes, or in proportion to the length of the shadow the sun casts at noon. The regularities of the heat are constantly interfering with the endeavors of the wind to smooth out the irregularities of the atmospheric pressure, and the work never ends.

The sun's rays warm up the air next to the earth more in some spots than others, for the amount of heat received at any particular spot depends largely on the color of the soil, the amount of moisture it holds, its protection from the wind, the shade, the clouds, and other things. The warmer air becomes lighter, expands, and sooner or later rises. The cooler air around flows in to take its place, and so a wind comes into existence. It may be brief and gentle when the disturbance is slight and local, or it may be great and continue long, if the disturbance has these characteristics. And when it once arises, it may have features which will perpetuate it, as we shall see later.

A brief and gentle disturbance of this sort, familiar to every one, is the little dust-whirl, seen at its best over a dusty road on a hot, calm summer afternoon. The air in contact with the dust becomes hotter and hotter until at some point, determined perhaps by a small projecting stone or the flight of a bird or insect, it breaks through the cooler stratum of air above, and for a few seconds forces itself up; then comes a quick inflow of air along the ground, bringing dust with it for a short distance around. This inflow whirls because it comes in unequally from the sides. The cause of the whirl is local and temporary, and the little reservoir of hot air is soon exhausted, the dust whirls in a beehive or spindle form for a few seconds, sweeps off in a jerky way to one side or the other, and comes aimlessly to the ground, bringing to a close a very brief but

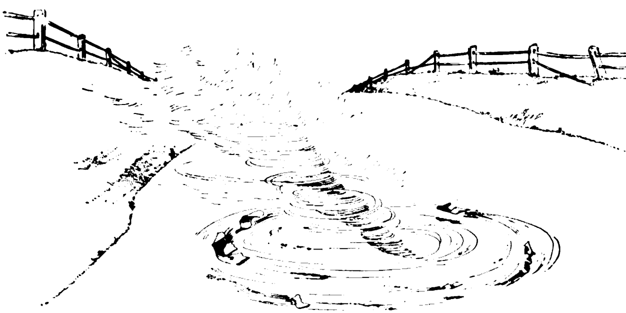


FIG. 10.—A summer dust-whirl over a country road. The direction of motion is against the hands of a watch.

pretty, interesting, and instructive phenomenon.

On a great scale the same general phenomenon occurs on the ocean in the calm latitudes not far from the equator, and there produces those large and very destructive storms called typhoons and hurricanes, causing terrific inflowing winds, traveling forward in well-defined paths, and lasting several days. Every gradation between the little dust-whirl and the enormous hurricane can be found, and the laws involved in the two are the same, except that in the greater and more lasting cyclones moisture or steam plays a part.

When the air next the soil or the ocean surface becomes hot it passes into a condition of unstable equilibrium, like dynamite or gunpowder. It then requires but very little to destroy the uncertain balance and cause the hot air to rise with a rush. A hurricane may be started, when everything is just ready, by the slightest thing—the motion of a bird through the air, for instance.

A current started downward by cold or by the air that rises elsewhere, may cause a higher pressure, and the air must flow away from it. For instance, the air on a hilltop or mountain gets chilled on a clear night. This increases its density—makes it heavier—and it will flow down into the valleys, displacing the air there. Air from behind follows it, and thus a system of winds is set up.

The differences of temperature make ascending and descending currents, and these cause horizontal motions of the air. The ascending and descending currents are not directly felt by us, because we are at the bottom of the ocean of air in which they occur. When in the free air—that is, anywhere else than on hill

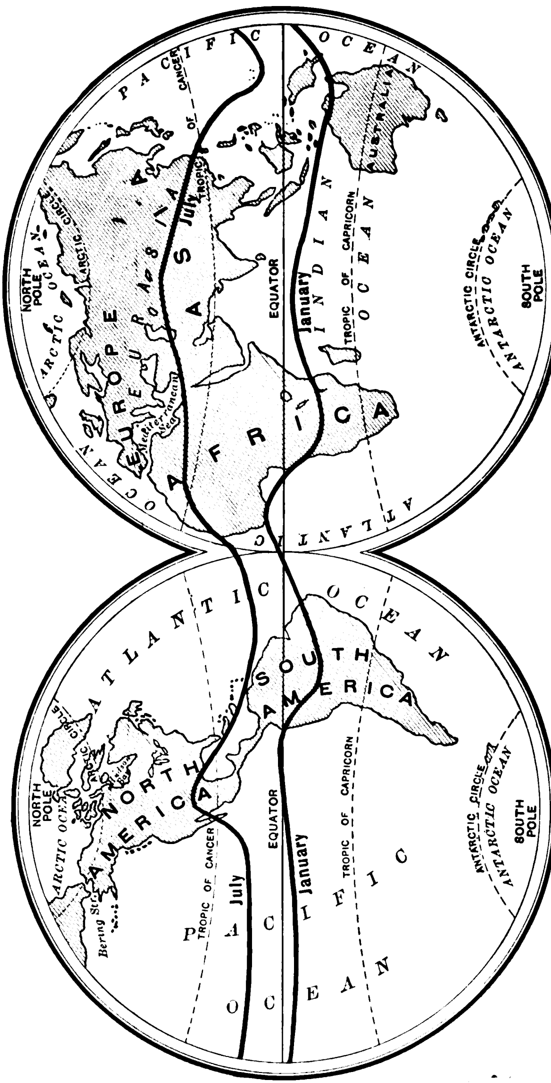


FIG. 11.—Heat equator wanderings. The heavy lines in the tropics show its highest northern and lowest southern positions.

or mountain slopes—they can be felt only at some distance above the surface. Our knowledge of them is obtained chiefly through reasoning; but the study of the clouds helps us much. The important part played in the weather by ascending and descending currents of air will become plainer as we proceed.

The horizontal winds near the earth's surface are those that we feel, and such we know very well. These comprise the general terrestrial system, the storm system, the annual and diurnal winds, and certain occasional winds due to mountains and hills.

Almost under the path of the sun each day lies the heat equator. It moves back and forth each side of the equator proper as the sun comes north in summer or goes south in winter. Along the heat equator the sun's rays warm the air and cause it to rise, so that there is a ring of rising air around the earth all the time. Under this ring the air is nearly calm, and above it there is more or less cloudiness.

To supply the place of the air which rises, the wind flows into the region of the heat equator. On the north side it flows southward, and on the south side northward. The rotation of the earth makes this wind fall back in its progress toward the equator, so that on the north side there is a ring of inflowing winds from the northeast known as the northeast trade winds. They are called trade winds because they help commerce, being fairly constant and steady over the ocean. On the south side of the equator there is a corresponding ring of southeast trades.

These rings extend about twenty degrees from the heat equator on each side on the

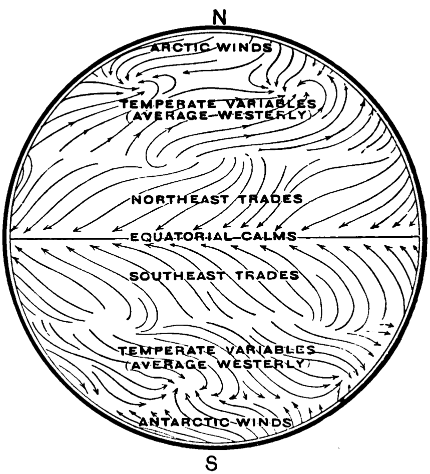


FIG. 12.—Rings and caps of the earth as shown in the winds.

oceans. On the land they are much broken up by mountain ranges and other features, which cause local weather conditions. Beyond these rings on each hemisphere comes a broad ring or zone of variable weather, where the winds are controlled by storms. And beyond these come the polar caps, the weather of which is not well known.

Thus we have for each hemisphere, counting from the heat equator, three rings and a cap of weather—the calm and quiet weather about the heat equator, the settled weather of the trade latitudes, the variable weather of the temperate zones, and the less known but probably strong and variable weather of the polar caps.

It is in the zones of variable weather, apparently, that the air which ascends at the equator begins to come down to the earth's surface again. The result is the prevailing winds from the west which occur in these zones when the weather is not controlled by storms.

CHAPTER VIII.

DIRECTION, VELOCITY, AND MEASUREMENT OF THE WINDS.

THE winds are named from the direction in which they come to us. A wind that comes from the northeast and travels to the southwest is called a northeast wind. The direction is indicated by the wind vane, and this always points to the direction from which the wind comes.

The velocity of the wind is expressed in the miles it travels per hour. A very light breeze, just enough to stir the leaves on the trees, has a velocity of about two miles per hour. A gentle breeze, which cools us in summer, travels at the rate of from five to seven miles an hour. A fresh breeze is traveling at the rate of ten or twelve miles; a strong one from fifteen to twenty—or at the rate of a freight train; a high wind from twenty-five to thirty, and a gale from thirty-five to sixty—as fast as the swiftest express train. A hurricane may have winds traveling from seventy-five to nearly one hundred miles per hour, and in tornadoes the velocity may be still higher.

The velocity of the wind may be measured by any sort of a windmill, but the form which is usually adopted is that of four hollow hemispheres on the end of four arms turning horizontally. A measurer of the wind is called an anemometer, and this form is Robinson's cup anemometer, named from the man who first developed its use in this way. The force of the wind is measured in several ways. A simple device is a pendulum which the moving air swings out to a greater or lesser extent from a vertical position and so measures the force of the wind. Or a flat board a foot square, with a spring behind it, may be carried on a wind vane so as to be always opposed to the wind. The wind will press the board back and compress a spring. The number of turns made is counted by a little device much like that on a gas meter.

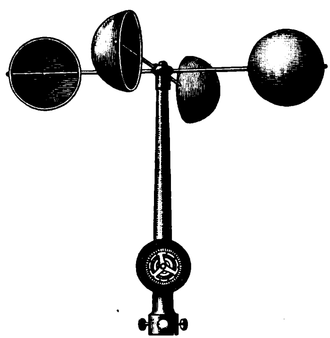


FIG. 13.—Robinson's cup anemometer. The cups move with the hands of a watch.

The force which the wind exerts differs with the form, size, and position of the surface exposed to it. The usual rule, which gives a fair average value, is that the pressure in pounds to the square foot may be obtained by squaring the velocity in miles per hour and dividing by two hundred. This would give at fourteen miles per hour a pushing force of one pound to each square foot directly opposed to it. A north wind of fourteen miles would make a pressure of one pound on each square foot against walls facing the north, against which it blows. This is not a severe wind, but for a small house it would give a pressure of four or five hundred pounds on the north side. For twenty miles an hour the pressure would be two pounds to each square foot; for forty miles (and such winds are not rare), eight pounds; for sixty miles, eighteen pounds, and so on. Buildings must be made strong, for a pressure of eight pounds to the square foot means one or two tons, and of eighteen pounds to the square foot from three to five tons pushing force against a small house.

It is this power that is used in windmills, but they are, generally speaking, so rude as machines that much of it is lost. The larger the mill, the less effect its various imperfections has, so that while a mill eight feet in diameter uses only about a tenth of the energy of the wind, one of twenty-five feet uses about a third. The first can do only about a twenty-fifth part as much work as a horse, while the last does about a third more than an average horse.

The wind is reduced by the friction of the earth's surface; its velocity is less on land than on sea, and in wooded countries than over open plains; it is less when it is close to the surface than when it is higher up, and it attains its greatest average velocity at a distance of some thousands of feet above sea level. The wind is also likely to change during the day, and averages greater in the afternoon than during the rest of the day. It often goes down perceptibly when the sun sets.

CHAPTER IX.

THE TEMPERATURE OF THE AIR.

IN records of the weather and climate the temperature of the air is always understood to have been taken in the shade. In the sun the temperature is higher and varies to some extent with the material and color of the thermometer used.

The highest temperatures on the earth are generally at the bottom of the atmosphere. As one passes up the temperature falls, and it reaches its lowest point at the limit of the atmosphere. How low it is there is not known, but it is several hundred degrees Fahrenheit below zero. The rate of fall in temperature varies much close to the earth, according to the season and the weather. At first it averages about three degrees for every thousand feet, but above this it changes more slowly.

At the earth's surface the variations of the temperature are due to the sun's rays, and these are so hot that, after losing a half or three quarters of their potency in passing through the atmosphere, they are still warm enough, when properly applied, to cook a dinner in a Dutch oven, or to run a solar machine.

Much of the heat of the sun's rays is lost at the upper surface of the clouds. Much which passes through the clouds or comes down through the clear atmosphere is, in fact, absorbed by the air itself, and warms it. Another part is expended in warming the soil and water, and still another in evaporating water, changing it into vapor or moisture. All this heat, however, is returned later to the air, and the latter is better able to absorb it when thus returned than when it comes directly from the sun. The heat of the sun's rays, which comes to us directly only in the day, may be distributed everywhere, and be returned to the air during the night.

Heat given off by the soil or water is more easily absorbed—one might say caught or trapped—by the air than that which comes directly from the sun. The difference between the sun's rays and the heat radiated from the soil is well shown in the hotbed of the gardener. The sun's rays pass through the glass with little loss, but the rays reflected from the soil can not pass back again through it without great loss. The heat is thus trapped by the glass, and the temperature inside rises much higher than that outside.

The meteorological temperatures show the balance between the gains and losses of heat by the air. The losses come in large part from the reflection and radiation of the heat into free space. This space is very cold and takes up all the heat sent to it. It is this loss that causes unseasonable frosts on clear nights. Another source of loss is found in the heat that is required to evaporate water, and this is going on all the time and at all temperatures. Still another loss is the heat used in warming up the soil and water to a greater or less depth.

The gains are as numerous. The air absorbs a part of the heat that passes through it. The heat taken up in evaporation is given out again when the vapor is condensed, and this may be at a great distance from the place where it was absorbed; the soil gradually gives out its heat to the air, and so does the warmer water; thus the heat comes back to the air again; but, as a result of these processes and of the delays due to them, as well as of the alternation of day and night, the supply of heat is uneven and irregular and the temperatures are never steady.

The temperature is lowest at night and highest in the daytime. It reaches its lowest point on clear nights at about daybreak, and its highest at about three in the afternoon. It is also lowest in winter when the sun passes nearest the horizon, and it is highest in summer when the sun comes up nearest to the zenith. The coldest days are in the latter half of January, and the warmest in the latter half of July.

The temperature is also very much modified by clouds. A layer of clouds is a sunshade by day and a blanket by night. It keeps the day cooler and the night warmer. Hence in stormy weather the temperature is more even, in clear weather more variable. The barometer and thermometer usually move in opposite directions. When one falls the other rises.

The highest temperatures ever observed in the shade have been in deserts not far from the equator; they run up to about 140° F.; the very highest recorded is 154° F. from the Sahara. The lowest known are from the great land areas under the arctic circle, in Siberia and North America. They run down to —50° or —60° below zero; and the very lowest recorded was — 96° below zero, in northeastern North America. Thus the absolute range of temperatures observed on the earth is 250°. In the

United States, outside Alaska, the range is probably not two thirds of that, and for any particular well-populated place about half.

The temperatures are measured by a thermometer hung in the shade, and free from all bodies which can conduct heat to it. The usual form is the mercurial thermometer; but the mercury used in it freezes at very low temperatures, and in high latitudes it must be replaced by a spirit thermometer. There are unfortunately two different thermometer scales in ordinary use. The first is that used by English-speaking people generally, and is called the Fahrenheit scale, from the name of the man who invented it. On this the freezing point for water is 32°, and the boiling point 212°. The other is that called the Celsius scale, from its inventor, but more often the Centigrade, from the number of degrees between freezing and boiling. The zero of this scale is at the freezing point of water, and 100° at the boiling point. Thus the Fahrenheit scale has 180° between freezing and boiling, and the Centigrade 100°. The Centigrade scale is usually employed by people other than those speaking English, and by the latter in scientific work. In this book all the temperatures given are those on the popular or Fahrenheit scale.

Lines passing through places on the map having the same temperatures are called isotherms. They correspond to the isobars for pressure. The isotherms on the weather map are usually drawn for each ten degrees.

CHAPTER X.

HUMIDITY, OR MOISTURE.

By humidity is meant the invisible water in the form of vapor or gas in the air. Steam is another name for the vapor of water, and is the same, whether it arises out of water by the slow process of evaporation from the surface, or that more rapid process of evaporation, throughout the mass which we call boiling. What comes from the teakettle or from steam-cocks is condensed steam—of the same character as fog and cloud. Humidity, moisture, the vapor of water or steam, is invisible, but when it condenses in the air it forms droplets, which when small are white. In this sense steam exists at all temperatures. It is only the surplus steam or moisture that condenses.

Matter has three physical states, the solid, the liquid, and the gaseous, and the change from one to the other is made by the addition or subtraction of heat. To change a body from solid to liquid, as when ice or iron is melted, or from liquid to gas as when alcohol or water is evaporated—heat must be added. When the change is the other way, heat is given out. It always takes the same amount of heat to make any and all these changes in the same substance.

The ordinary natural substances remain unchanged through the whole range of weather temperatures; iron remains solid, and the metals, rocks, and soil are unmelted through all weather changes. On the other hand, all the gases of the atmosphere remain gaseous throughout the weather changes. Oxygen, nitrogen, and carbonic-acid gas require enormously lower temperatures than the weather makes to change them to liquids.

The only natural and common substance that changes its physical state in the range of meteorological changes is water, and it passes through the series of three steps. In winter it is often solid and when high up in the air it may be in solid particles in summer. Its solid forms are ice, snow, hail, hoarfrost, and minute ice spicules. In high latitudes in winter liquid water can be obtained only by melting ice. In summer and in the tropics water in the solid form does not exist at the surface, but may do so on mountain tops or at some considerable elevation in the air.

The change from ice to water occurs at the temperature of 32° F., but that from ice or water to moisture or vapor may occur at any temperature. There is always a considerable amount of water vapor in the air, but much more in the summer than in the winter.

This change in the physical state of water is going on constantly, and with each change heat is absorbed or given out with a corresponding change in the temperature of the air. If the water is condensed it warms the air, and if it is evaporated the air is cooled, and this heat, taken up at one place may be given out at a far distant one. We can think of the molecule of water as a porter carrying its little load of heat from the place where it was evaporated to the place where it is to be condensed. This may be a distance of hundreds, perhaps thousands of miles, and the heat taken up at the surface may be liberated high up in the free air.

Water is the carrier and distributor of heat in the atmosphere. It gives drink to all thirsty things in Nature, whether they are organic or inorganic. In the air also it is the only important gaseous element that varies, and to it are due many varying properties of the atmosphere. For instance, it is lighter than air, and by its less weight and variable amount it changes the density and the weight per cubic foot of the air. If we add to the offices of water these others—that there are many chemical combinations which could not take place without water, that water is the only great natural liquid of Nature, and that it aids in transferring many substances by holding them in solution—we will understand how important this familiar substance is. And in no domain of Nature is it more important than in the work of the atmosphere.

In its gaseous or vapor state of humidity it comes from evaporation, and this process constantly goes on from all surfaces containing water, unless the air in contact with such surfaces is saturated; it goes on even from ice as is shown by the way ice slowly dwindles without melting if the air is very dry.

But evaporation occurs not only from the surface of water, but from all surfaces which are moist. This is the constant drying-out process, and the vapor poured from the surface of moist soil may be more abundant than from that of pure water, as from a surface covered with living turf, for the grass is chiefly occupied in pumping water from below, and throwing it out into the air as vapor. It does this in order to get the nourishment it needs, which is held in solution in the water.

Moisture, then, is constantly passing into the air by evaporation. By this process the molecule of water casts off the bonds that held it to other molecules and is free to travel for itself through space. It does this, and its motion is so rapid that it is soon far away from the spot where it gained its freedom. The diffusion of the vapor of water through the air is far more rapid than its distribution by the winds could be.

The limits to this diffusion are to be found in temperature. The lower the temperature, the fewer the molecules which have freedom of motion. If there are too many, the surplus molecules must combine in the process of condensation to make dew or hoarfrost, fog or cloud, or hailstone, or some other form of water or ice. If the temperature rises, a part or all of these may pass back into the vapor state; if it falls, more vapor is condensed. The temperature at which condensation begins is called the dew-point. At the dew-point the air is saturated—that is, at the temperature called by this name the air has as much moisture as it can accommodate. If the temperature rises, more water can be evaporated—and will be, if it is available; if the temperature falls below the dew-point, some of the moisture will be condensed.

The amount of moisture in the air is expressed by its weight in grains to each cubic foot. This amount is called the absolute humidity. The absolute humidity for saturation at 30° below zero is only an eighth of a grain. At 0° it is over half a grain, at 32° about two grains, at 60° nearly six grains, and at 100° it is twenty grains. The absolute humidity is less in winter than in summer, at night than in the day, in cold climates than in hot, and it decreases rapidly as one ascends in the air.

The vapor of water in the air may be looked on as an atmosphere in itself. As such it is much lighter than the dry air, and its depth is perhaps much less than that of the dry atmosphere, for the humidity thins out rapidly upward. As an atmosphere, however, it exerts a pressure of its own, which is often used by meteorologists, and is called the vapor tension. It is very much less than the pressure of the dry air, being generally less than an inch of mercury, and very rarely, under the most favorable circumstances, being more than two inches.

In practical questions, involving the drying-out quality and the rapidity of evaporation of the air, another expression is used for the humidity. This is relative humidity, an expression of the ratio between the moisture the air contains and that which it would contain if it were saturated. For instance, if the air has only half as much moisture as it could hold, the relative humidity is 0.50; if three quarters, 0.75. Usually the decimal point is left off, and these numbers are simple percentages. Commonly the relative humidity is above 75. If it is between that and 50, things dry out and furniture becomes loose in the joints. Below 50 the drying is rapid and the sensation of dryness is distinct. In some desert places the relative humidity may descend to 10, or even 5, and lower.

The accurate measurement of the humidity of the air requires an elaborate experiment. Meteorologists have contented themselves with a less direct method, where two thermometers are used, one with its bulb wetted, the other with its bulb dry. The cooling due to evaporation is thus obtained, and from this and the temperature the humidity may be calculated.

CHAPTER XI.

DEW, FOG, AND CLOUD.

When condensation occurs the free and independent molecules of the vapor must rush together to enter again into the closer bonds of a liquid. There are probably myriads of them in each droplet of dew, fog, or cloud that is formed. That they rush together is due to the fact that there is not enough heat present to keep them apart. The point toward which they rush is determined by such solids or liquids as happen to be already present.

In the case of the dew free surfaces on which the condensing water is deposited are furnished by the soil, stones, plants, and other things in connection with the ground. When the sky is clear and they are not heated by the sun, these objects lose heat by radiation and become chilled. If at the same time the air is still it becomes chilled by contact with the rock or other body, and deposits upon it the condensed moisture. The operation can be seen on an ice pitcher on any hot summer's day. The ice chills the walls of the pitcher until the air in contact with them is cooled below its dew-point and deposits a copious dew upon the pitcher, that being the object contact with which causes the air to cool.

Dew "falls" when the air is calm and the sky clear. It is most likely to fall, and is most copious, at about daybreak, which is the coldest and calmest part of the day; but it may begin before sunset the evening before. It can not occur where the sun's rays have free access, for they heat the solid objects until they are warmer than the air; nor can it occur unless there is enough moisture in the air to give a dew-point above the temperature of the bodies chilled.

Hoarfrost is simply dew deposited at temperatures below freezing. It is formed under conditions otherwise the same as dew, but, unlike the latter, the deposit can be made in windy weather. When a very moist air sweeps across small bodies, such as branches of trees and electric wires which are below the freezing point, the hoarfrost may continue to be deposited on them until they become so loaded as to be broken down. A familiar illustration of the formation of hoarfrost is that to be seen on the window panes in winter. The air of the room has a higher dew-point than the temperature of the panes of glass, and the little crystals of frost are therefore deposited on them. These crystals are flat and applied closely to the pane, because the chilled air extends but a very small distance from the pane. The flowery patterns are due to the laws of crystallization of water; they are also seen in the hoarfrost, and can be found in ice when it is carefully and slowly melted in such a way as to let the compacted crystals free themselves from each other.

With the dew and hoarfrost, the free surface on which the condensation can be made is easy to find, but in the free air, where fog and cloud are formed, such surfaces are not visible. Still, the constant deposit of dust in quiet places shows that the air must contain innumerable minute particles which float, or slowly settle, in it. And these can be made visible by admitting a beam of sunlight in a darkened room by the many motes in its pathway, from which the light is reflected. The dust in the atmosphere is fairly universal, for it is even found deposited on the glaciers in the interior of Greenland.

Besides these particles, which can be rendered visible by a beam of light, and are relatively large and coarse, observation and experiment has proved that there are many minute living germs floating freely about in the atmosphere. They are so numerous, indeed, that only by the most careful and exacting cleanliness can they be kept out of such places as wounds, where they may do much harm.

There is yet another and very abundant source for particles in the air which appear to be still more minute. Most solids when warm give off many extremely minute portions of their substance, and some, as sulphur, give them off in great numbers. When any object is burned many of these ascend into the air. The existence of such particles gives rise to a phenomenon of light called diffraction, which consists of the turning aside of a beam of light and separating it into the prismatic rays of which it is composed as it passes the edges of opaque bodies, causing the appearance of fringes of different colors, and their presence enables clouds or fog to be easily formed. There has been a recent illustration of the great quantity of these particles which may be poured out into the air during volcanic eruptions.

In 1883 a small volcano in the Straits of Sunda blew up with a violent outburst. It caused the death of scores of thousands of people, created an enormous wave of water which traveled far, made a wave of air which went around the world several times, and it poured out such an amount of pumice that great quantities floated away in extensive fields to so distant a place as the Cape of Good Hope. But the feature of especial interest here is that the volcano threw out into the air such enormous quantities of the minute particles above mentioned that they spread all over the earth, except to high latitudes, and by diffraction gave for months an unusual splendor to the sunsets.

It appears, then, that there are plenty of minute particles in the air to afford the nucleus for the droplets or crystals of cloud and fog. The question arises, How are they suspended in the air? Water, whether as a liquid or in crystals, is always heavier than air. How is it, then, that the fog is kept suspended overhead for hours, and the clouds float high above the earth for days together?

There are two true, and yet different, answers to this question. The first is that the droplets, and crystals as well, are not suspended but do actually fall and must fall. In no case do they stand still, but they fall slowly because the air offers resistance to bodies passing through it. This resistance increases with the velocity, of the falling body, but at a faster rate, and sooner or later puts an end to any increase in velocity. After that the body falls uniformly. The smaller the body is, the sooner this takes place, and in the case of the minute droplets it comes so soon that their rate of falling is only a few feet, or even a few inches, per hour. They fall so slowly that the effect is much the same as if they stood still. Even the relatively larger raindrop or snowflake is not permitted to fall very fast.

The second answer to the question is that the cloud or fog marks out a space in which the temperature is below the dew-point, and that elsewhere the temperature is above the dew-point. Within the space marked out by cloud or fog condensation can take place; outside of it this can not take place, because temperature and humidity are not right for it. Meantime, inside this space the droplets of a cloud fall slowly, and some of them must pass out of it. They are then evaporated and disappear, thus preserving intact the bottom of the cloud.

By remembering that a cloud represents only a condition, a certain relation between temperature and humidity, we can understand how clouds can travel so fast. One sometimes sees them overspread the sky in a few minutes, extending themselves at the rate of perhaps a hundred miles an hour. It is the condition that extends itself, and this does not necessarily mean the bodily motion of the cloud ; the chilling of the air below the dew-point at that height at which the cloud appears is what travels, and for this a movement of the air is not really necessary.

A fog is a cloud at the ground, and a cloud is a fog high up in the air. If one sees a cloud about the top of a mountain and climbs up to it, it always proves to be a fog. The conditions are very much the same for both, but fogs are more distinctly diurnal—that is, more dependent on the time of day. Both cloud and fog are produced by cooling the air below the dew-point, or forcing the moisture into the air until super-saturated. The latter is the process by which a teakettle or locomotive makes clouds or fogs on a small scale. The way in which fog is formed in Nature is by chilling the air by nocturnal radiation or by mixture with cooler air. The chief way in which clouds are formed is by ascending currents of air.

The method employed in ascertaining the heights of clouds is the same used for obtain-ing the distance of inaccessible objects—such, for example, as the peaks of high mountains. Use is made of the triangle, and the method is called triangulation. Observers at *A* and *B* observe the same point *C* on the cloud and note the angles *C A B* and *C B A*. The distance *A B* is measured, and with these three

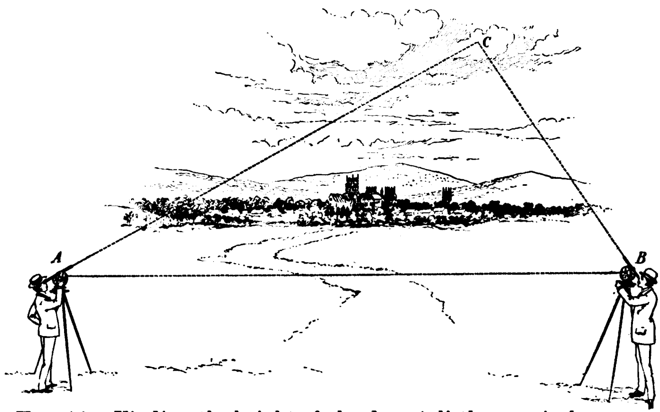


Fig. 14.—Finding the height of clouds. A little practical geometry. It is better if cameras are used instead of theodolites.

parts of the triangle the length of the other two lines can be obtained. A telephone connection between the two observers enables them to fix on the same point for observation, and if they take photographs the problem can be worked out from the pictures. A series of observations or photographs gives them the movement of the cloud.

Clouds vary in height from two hundred feet to ten miles. They are generally from a mile to five miles above the earth, and are generally higher up in summer than they are in winter. They travel at rates up to a hundred miles an hour, and the motion averages a half more in winter than it does in summer.

There are three fundamental forms of clouds: cirrus, cumulus, and stratus. The cirrus, or vail cloud, is fine, feathery, of a silky texture and luster, and so thin that stars can easily be seen through it. It is the highest of the clouds, being from three to ten miles above us. These heights from the surface of the earth were determined at the Blue Hill Meteorological Observatory near Boston, Mass., as were the measurement of all other heights and all rates of motion here given. The average altitude overhead for cirrus is six miles. The color of cirrus is pearly, and its luster is due to the fact that this species of cloud is made of ice crystals. Cirrus, of all clouds, moves the most rapidly; its rate averages eighty miles per hour, being sixty-three in summer and ninety-eight in winter.

It is in many respects the most interesting of cloud formations. It is the highest, the swiftest, the thinnest, and the only one generally composed of ice crystals. It is the usual precursor of storms, preceding them by two or three days. In some regions, as in the Pacific northwest, it is a rare form. On the other hand,

FIG. 15.—Cirrus.

in the Northeastern States it is one of the commonest. It is the form that shows the mackerel backs, and the filly's tail, and the long polar bands, so called, which stretch across the sky from some point in the horizon to a corre-

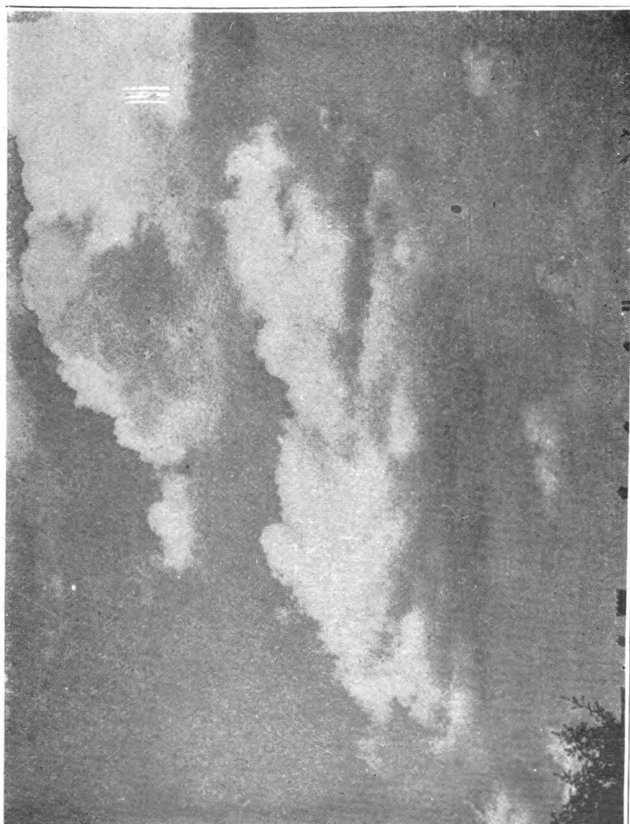


FIG. 16.—Cumulus.

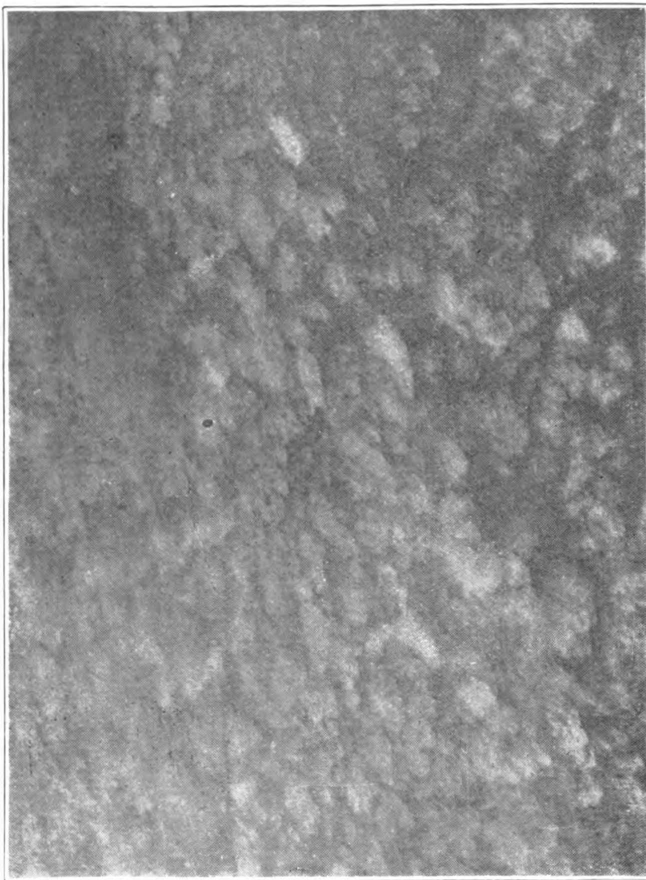
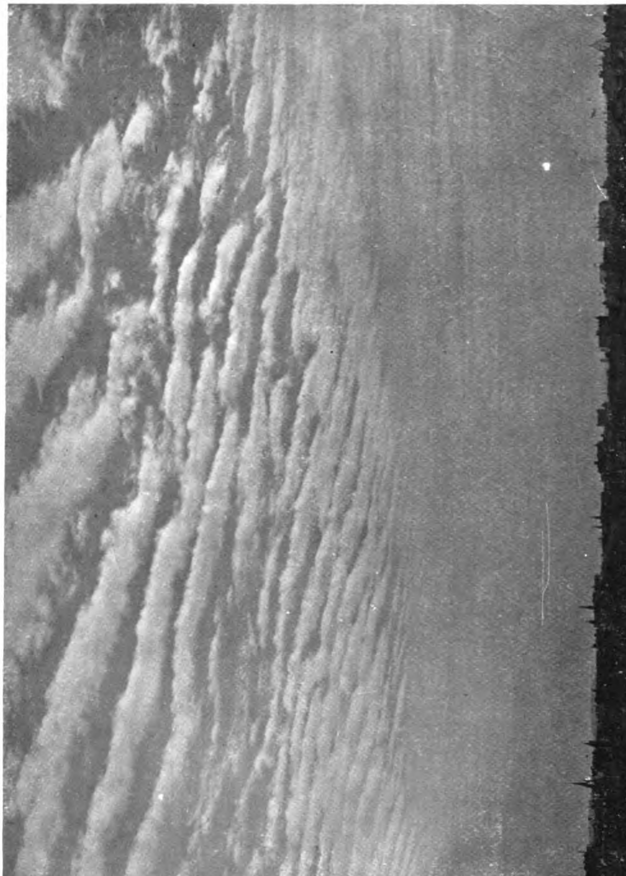


Fig. 17.—Cirro-cumulus.

sponding point on the opposite side. In all these cases, however, it is in progress of passage to one of the forms which follow. In the filly's tail, which looks like a wisp of fine slender hairs, it has taken the first step toward the stratus or blanket cloud, and in the polar bands this progress is still farther advanced. The latter has gone so far that it would be called cirro-stratus.

The mackerel backs, or mackerel sky, and the curdled, fleecy clouds of a purer white form a step toward the cumulus, and are called cirro-cumulus; these are white balls, arranged in groups or rows.

The second fundamental cloud form is the cumulus, or mountain cloud. It is very white above, unless tinted with gold and rose color by the rising or the setting sun, and rounded, domed, or anvil-shaped. It is the thickest of all the clouds, standing generally isolated from the rest, flat and darker at the bottom. When favorably situated it casts a distinct shadow, and when this reaches the ground it enables a single observer both to measure its velocity and to triangulate for its height. The typical form of the cumulus is a cloud of medium elevation, varying in horizontal extent from two thousand feet to two and a half miles. Its thickness averages about half a mile. The usual height above the surface of the earth is one mile. The cumulus often stands still, but when it does travel it goes at the rate of from



From a photograph by A. J. Henry.

FIG. 18.—Wave form.

twenty to thirty miles an hour, averaging for the year about twenty-five miles.

This very characteristic and picturesque mass of vapor is a warm-weather cloud form. It is most common in hot climates, in summer, and during the warmer part of the day. Its existence is due to the ascent of the air, and the growth of the cloud can often be seen if it is watched through a telescope. Even with the naked eye one can often see sudden bulgings and twistings about the rounded protuberances. Sometimes its top passes off into a cirrus veil, called a false cirrus. The bottom is occasionally rent by winds, in which case the detached parts are called fracto-cumulus.

The stratus or blanket cloud is the third form. It is darker in color than the others, a dark gray, with sometimes a brownish tinge. It forms a layer or blanket of no great thickness, pretty evenly spread over a larger or smaller portion of the sky. Seen near the horizon, it seems but a band, but when above the observer it spreads like a blanket, thick enough to shut out the sun and stars. It floats nearest the surface of the earth of any of the clouds, averaging only from a quarter to a third of a mile above the surface. It moves, on an average, at a velocity of about twenty miles an hour; being sixteen in summer and twenty-three in winter.

The stratus is only a bank of fog elevated above our heads. It is the cloud of melancholy

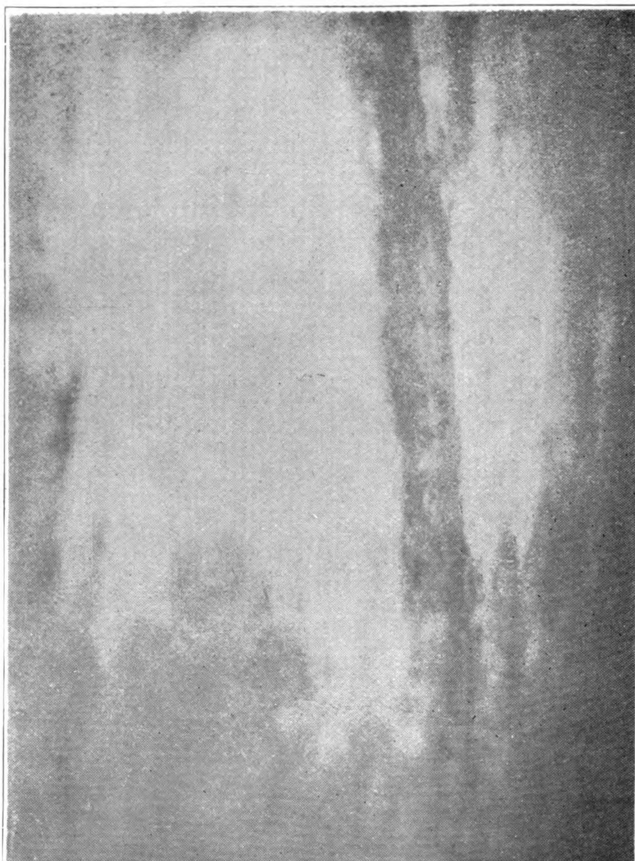


FIG. 19.—Stratus.

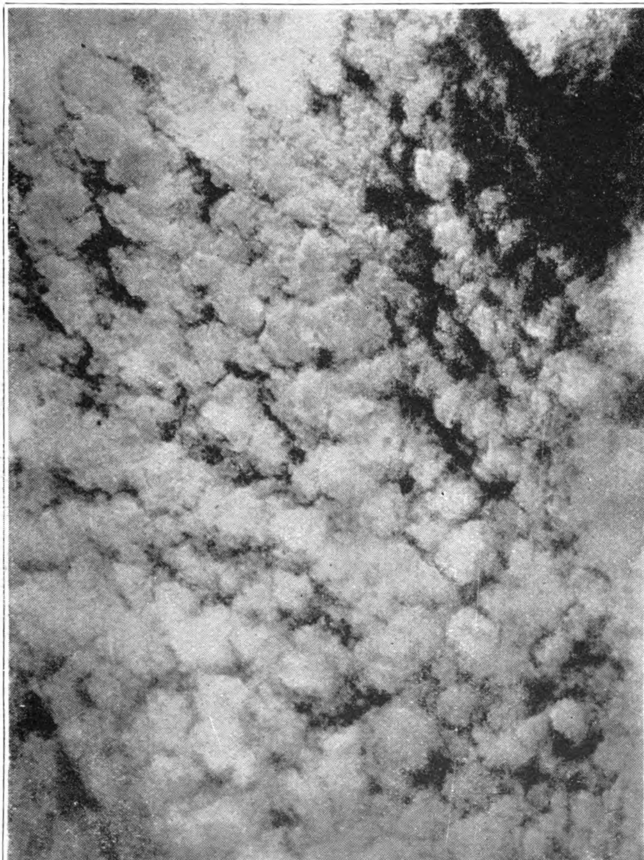
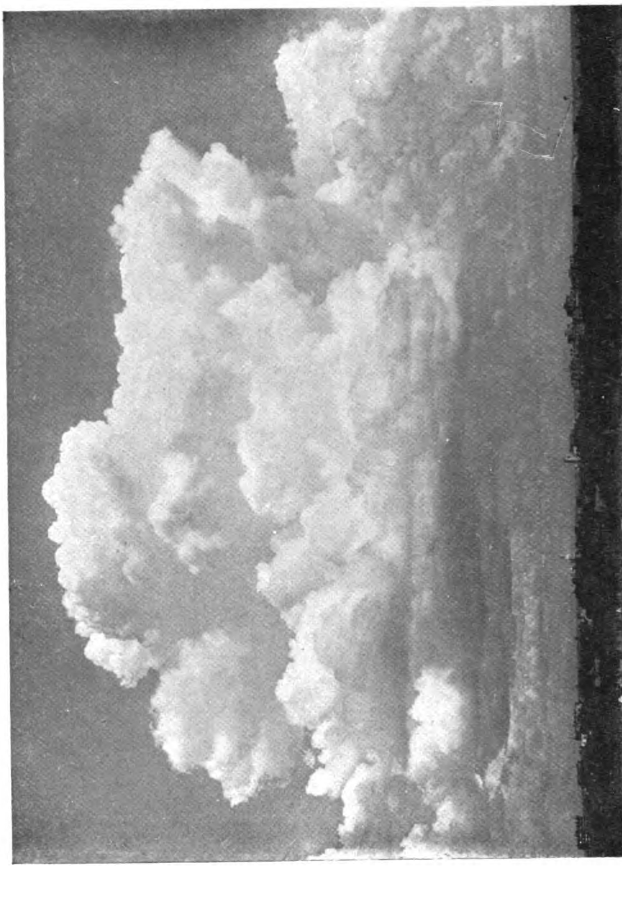


FIG. 20.—Alto-cumulus.

weather, of winter, and of snow. It is the least interesting and least picturesque of the clouds.

There is a fourth form called nimbus, but its only character is that rain or snow is falling



From a photograph by A. J. Henry.

FIG. 21.—Cumulus cloud.

from it, and this does not really distinguish it from the others, for precipitation occurs as well from the cumulus and stratus and from intermediate forms.

With the three fundamental forms of clouds well in mind the reader can, by observation of the sky, work out the intermediate forms for himself. This is the more necessary, as illustrations can not bring out clearly the delicate forms and shades of clouds. The Weather Bureau, whose pictures we employ, uses ten names for cloud forms. These, in order from the highest to the lowest, are the cirrus, cirro-stratus, cirro-cumulus, alto-stratus, alto-cumulus, strato-cumulus, cumulus, cumulo-nimbus, nimbus, and stratus.

The alto-stratus is a thin, high stratus, of a gray or bluish color, lower than the cirro-stratus, and not fibrous or feathery. It is common, and is described by the name which means high stratus.

The alto-cumulus is a lower and denser cirro-cumulus. It is a dense, white, fleecy cloud, composed of large balls in flocks or rows, generally close together. It looks like a large number of small, high cumuli close together.

CHAPTER XII.

PRECIPITATION: RAIN AND SNOW.

THE enormous amount of work done by the weather can be best understood from the rainfall. If a hundredth of an inch of rain falls—and this is a very light shower—it will deliver to a small city lot, one hundred and thirty gallons of water. On an acre the fall will be a full ton, and over a square mile it will be the enormous quantity of seven hundred and twenty tons of water. More than ten times such an amount often falls in an hour, and it all comes from the height of about half a mile. The atmosphere must raise this amount of water to this height and keep it there until it is to fall to the earth.

It is raised as moisture, but falls as rain or snow. This is called precipitation, from its exact similarity to the precipitation in the test tube of the chemist. The droplets and ice crystals which form the elements of the cloud gradually or suddenly grow until their weight is enough to bring them to the ground before they can be again evaporated. The resistance which the air offers to their passage keeps them from falling too fast. The drop soon acquires such a velocity that the air prevents it from going any faster. The larger and heavier the drop the greater is the speed at which it falls, but it is never great enough to injure us or do serious damage to animals or plants. Were it not for the resistance of the air, a drop of water, notwithstanding that it is fluid, falling from the height of half a mile would be as dangerous as a bullet. The swiftness and force with which a projectile travels can be made sufficient to compensate for any softness or yielding quality it possesses. A candle when fired from a gun will pass through a board.

Snowflakes present a much larger surface to the resistance of the air, and so fall more slowly than do the drops. Hailstones are made under conditions which permit them to attain an average size much greater than that of raindrops. In such cases they may fall so rapidly as to cause much destruction. Scotch mist is a form of precipitation where the drops form in fog and are very small. They are large enough to fall visibly, but their fall is very gentle.

The intensity of a rainfall varies from the Scotch mist or the few scattering drops from a cumulus on a summer afternoon to a rate which may give a depth of one inch, or even more, in an hour. Such heavy rains are likely to cause inundations in the country and an overflowing of the sewers in the city. They rarely occur except in dry climates; for such climates are subject to the double disadvantage of having a comparatively small annual rainfall, but having that fall in a few heavy and destructive showers. The heaviest rainfall recorded in the United States is eighteen inches an hour. It occurred in southern Idaho. The most favorable rain for all purposes is a gentle and long-continued one, and that is the most likely one to fall in moist climates.

A snowfall is equivalent to about a tenth of its depth in water—that is, a snowfall of ten inches would, when melted, make a layer of water about one inch deep. A deep snowfall, though injurious to traffic, is beneficial to farmers. While it lies on the ground it prevents frost from penetrating the soil and it protects delicate plants from freezing, and by the cooling it produces when it thaws it retards and even prevents the sudden and extreme changes of temperature which are so injurious to life. Moreover, by lying late in the spring it keeps plants from sprouting too early and so being nipped by frost.

The snowflakes are of varied and beautiful forms, and, in accordance with the laws of crystallization of water, are sexanary or governed by the number six. Six-rayed stars are

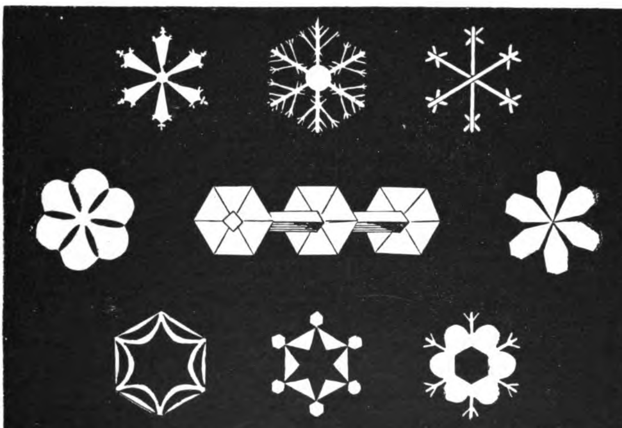


FIG. 22.—Snow crystals.

the most common form of snowflakes in mild weather, and the enormous flakes that sometimes fall at the beginning or end of winter will be found, when examined, to have the six rays, each branching. As the weather grows colder, the flakes become simpler and smaller, until they are often reduced to slender six-sided prisms with sharp ends or to flat hexagonal scales. The needle-shaped prisms are characteristic of the blizzard, and it is the stinging which they cause when driven against the skin by a high wind that causes most of the suffering in these dreadful storms.

Some winter fogs are made up of ice crystals instead of droplets. They are practically cirrus at the ground, and have to an even higher degree the translucent, lustrous appearance which these clouds show. They are somewhat iridescent in the sunlight, and the effect is so beautiful and striking that once seen it will never be forgotten.

The measurement of the precipitation is very simple in theory, but in practice accuracy is very difficult to attain. The essential form of a rain-meter is, of course, some sort of a cylindrical receiver exposed to the rain; but rainfall is very sensitive to gusts of wind, wind-breaks, and shelters. A can placed on the grass in an open place will give correct measurements if the rain fall during a calm; but, if there is any wind, eddies will form around and carry the raindrops outside of it, making its catch less than the fall. The easiest way to remedy this is to sink the top of the receiver to the level of the ground.

The total amount of a rainfall usually varies with the elevation above the ground. The raindrops continue to grow during their fall if, as is generally the case, the air below is at or near the dew-point. The drop itself forms a free surface for the deposit of the new condensation, and is, moreover, generally cooler than the air. In dry climates, however, the opposite may be the case, and the drop when it reaches the ground may be much smaller than when it left the cloud. Indeed, over the dry plains of the Southwest heavy rains are often seen above which never reach the ground. Strange as it may appear, it is no unusual thing there to be under a shower without protection and yet be perfectly dry. In such cases the raindrops are completely evaporated by the layer of dry air between the cloud and the earth.

It is commonly thought that electricity plays an important part in causing weather. It is true that thunder and lightning occur in many storms, and that the rainfall is often heavier immediately after a lightning flash. Rain clouds undoubtedly develop a strong electric tension, and probably electric charges on the surface of the drops play some part in preventing them from growing or coalescing when they come in contact with each other. Just how far these things are necessary and how the work is done is yet uncertain. So far as actually known, the electric phenomena are rather a result of the storm than a cause. That electricity plays an important part in the economy of Nature in general is beyond a doubt, but storms often occur with but faint signs of electric disturbance.

CHAPTER XIII.

GENERAL STORMS, CYCLONES, OR LOWS.

THE most remarkable discovery in the modern study of the weather is the cyclone. By this word is meant, not necessarily a furious, destructive storm, but only a circular mass of air—a flat, thin vortex, shaped like a wafer and having a system of internal motions of its own. These motions may be so intense as to be very destructive, but nine times in ten the cyclone is a very gentle creature—in some cases so gentle that, though it passes over our heads, it requires close observation and delicate instruments to detect it. It is not once in a hundred times that a cyclone does any damage to man, even when we count an occasional stroke of lightning. The word cyclone, however, is so frequently misunderstood that meteorologists generally use others, except when they write for their fellow students of the weather. They often call these masses of air general storms, because they are great disturbances of the atmosphere, and therefore are storms in a proper sense of the word, though not always in the popular sense. To avoid the misapprehension that the word storm creates, meteorologists often use the word "low" as a substitute for "cyclone" or "general storm," because it has no evil popular associations with it. And this word is appropriate, for it expresses the state of the barometer in a cyclone. Besides, this is the word used on the weather map to mark the center of the cyclone. (See the map on page 101.)

The cyclone appears on the map as an area of low pressure. Around the center the isobars are closed up, inclosing an area or island of low pressure. The inclosing isobars are usually nearly circular, but sometimes oval or even irregularly elongated. When they are so elongated that a projection or trough extends toward the equator, they are likely to develop a series of local storms of great interest, but these are to be discussed later. The more nearly circular the isobars, the more regular is the storm, and they are more likely to be circular in intense storms than in gentle ones.

At the center itself the pressure of the air is the lowest, and it rises as one passes out from this point in any direction. The isobaric lines on a weather map are much like the profile lines on a topographical map, and many of

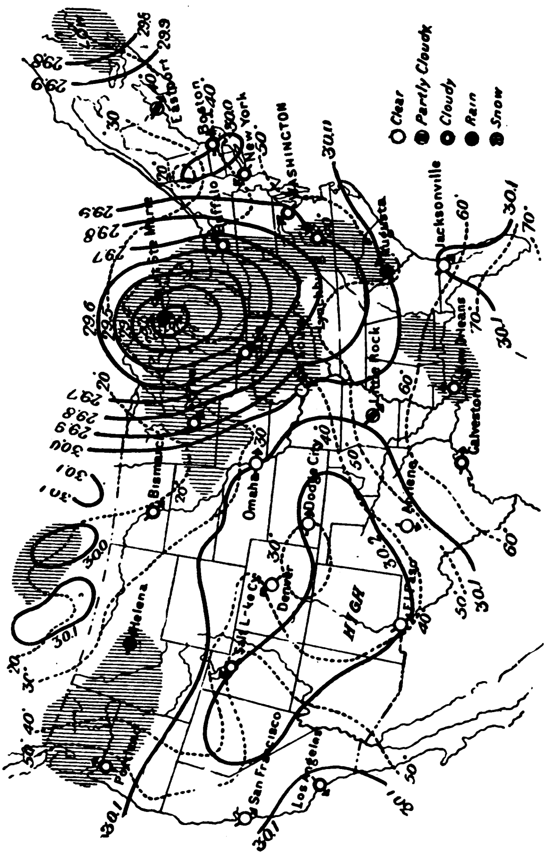


FIG. 23.—A weather map for the United States. The heavy black lines are isobars representing the pressures marked at their ends. The broken lines are isotherms. The small circles represent the stations, and the symbols in them the state of weather at the station. (Since this map was engraved the symbols have been changed. See p. 208.)

the descriptive words of the former are taken from the latter. The low represents a valley, and the increase of pressure in all directions from it represents the slope up from the valley. This slope, gentle or steep at first, as the low is gentle or intense, is always gentlest on the advancing or eastern side, and steepest on the rear or western side. The change in pressure reaches far in advance of the other changes, except perhaps that of the clouds. The barometer often begins to fall two or three days before the center of the cyclone comes on; hence the use of the barometer in predicting the weather.

The temperature in cyclones changes just the other way from the pressure of the air. When the pressure rises the temperature falls, and when the pressure falls the temperature rises. There is thus a definite relation between the isotherms and the cyclone, as is plainly shown on the weather map, page 101. The isotherms rise or become more northern in the vicinity of the low. They fall or become more southern in the neighborhood of a high—the opposite form to be discussed hereafter. In general the temperature is higher during a low or cyclone than in ordinary weather, and decidedly higher than during a high. This is owing partly to the blanket of clouds which cuts off radiation and so prevents the loss of heat by radiation from the earth to the sky, and partly to the condensation of moisture going on in the low. In great and intense cyclones, as typhoons or hurricanes, this heat is described as being so great as to be stifling. Ordinary gentle cyclones do little more than to equalize the extremes of day and night.

The winds in a cyclone are of especial interest. They were the key to the discovery of the true nature of the cyclone. If the winds on the specimen map are carefully compared, it will be found that they show a strong tendency to turn toward the center of the low, or rather a little to the right of the center. The winds at any station are likely to be more or less affected by the character of the country around the station. For instance, at Cincinnati they are more likely to be recorded as passing up or down the valley of the Ohio River than in any other direction. At Denver they are more likely to pass north or south along the range of the Rocky Mountains than east or west across them. And so it is for many stations. The local conditions are likely to give special direction to the winds at the earth's surface, where the observations must be made.

To avoid these local variations, we take the average directions from many weather maps, and then find that the winds about a cyclone center are arranged as shown in the dia-

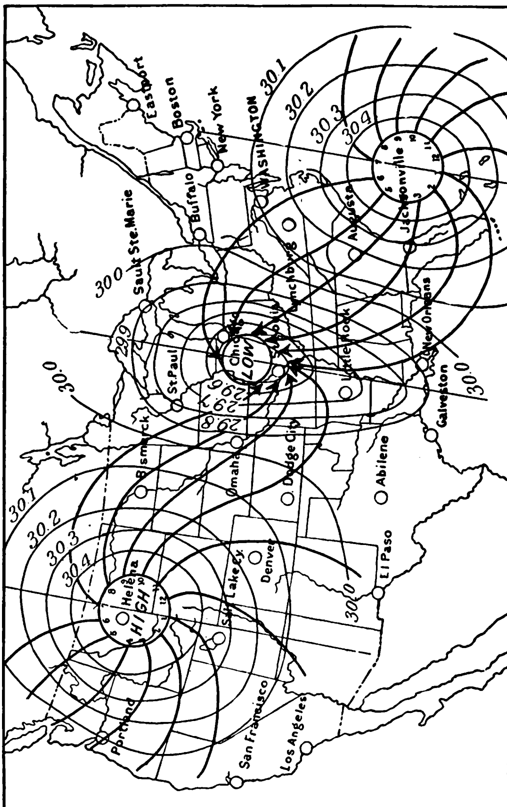


FIG. 24.—Inflowing winds of a cyclone or general storm or low, with its possible relations to the anticyclones or highs.

(From the Popular Science Monthly for July, 1898.)

gram (Fig. 24). They flow in spirally toward the center, and the direction of the whirl is, for our weather maps, always the same.

We shall now have to define the direction of a whirl or turn on the earth's surface in such a way that it can be easily recognized. This is not only desirable in order to give clear ideas, but it is necessary in weather study, because it fixes the succession of winds to be expected when a storm center sweeps over us. To fix and define the direction of motion, let us imagine a clock or watch lying on the ground, face up. Then, if the wind move or turn in the same direction as the clock hands move, we may call it clockwise rotation; in the opposite direction—that is, against the hands of the clock—contra-clockwise; then the whirl in the diagram is contra-clockwise, for it passes around in a direction contrary to that of the hands of a clock. And this is true for all great whirls in the northern hemisphere. They are contra-clockwise.

Great whirls in the southern hemisphere turn in exactly the opposite direction. They are clockwise. That the directions are opposite in the two hemispheres of the earth indicates that they are due to some guiding principle which is in an opposed direction on the two sides of the equator. It is a result of the rotation of the earth on its axis, and it is a very interesting proof that the earth does turn. The explanation of how the rotation of the earth causes these two opposite twists is difficult, and requires some space. It is so important that it will be made the subject of a separate chapter. Here it is enough to know that the turning is contra-clockwise in the northern hemisphere, and clockwise in the southern.

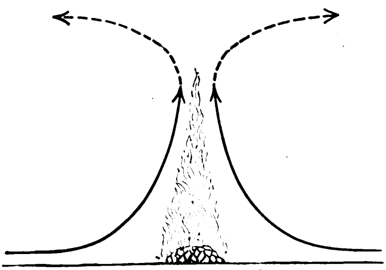


Fig. 25.—Scheme of vertical currents about a great conflagration in the open air on a calm day. They are much the same at the center of a great general storm, only more extensive.

It appears that the air about a center of low pressure, for hundreds of miles on each side, is pouring into this center, and that it is not heaped up there, for the pressure at the center is lower than elsewhere. The air then must pass out somewhere, and it can pass out only by going up. The condition is like that often seen about a great fire. The air flows in at the bottom and up at the center, as in the diagram (Fig. 25). And so we have the foundation of a great whirlpool in the air, something like one in water, but with the axis turned up instead of down.

The air which rises can not, however, continue to do so indefinitely. It must sooner or later flow off at the sides. This can be seen in the smoke and sparks carried with it in the small vortex made by a fire in the open air. In the great natural cyclone this outflow can be regularly observed in clouds and on mountains.

If the currents of air in a cyclone could be made visible, and we could take a section of it through the center and look at it from the side, it would look like the diagram of Fig. 26.

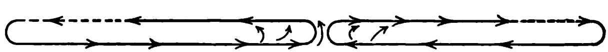


FIG. 26.—Probable appearance of a vertical section of a general storm, cyclone, or low, but exaggerated in height. It is five hundred to a thousand miles across and only a mile or two high.

We are to think of it as of the form of a wafer or flat round cake, but the diagram is too thick for the breadth. In fact, it is thirty or forty times too thick; for the thickness is there one thirtieth of the breadth or diameter, while in Nature it is only about one one-thousandth. The dotted lines in the figure complete the round of air. They have not been observed, but probably exist in some places and not in others around the margin.

The outflowing winds above have also a spiral direction, but the direction being outward, the twist is the opposite of that of the inflowing winds below. Seen from above, their turn is clockwise, but the twist is much greater than that of the inflowing winds below.

Putting all these things together, we get the following important rule:

If an air whirl is large enough to have the earth's rotation affect it appreciably, then in the northern hemisphere the inflowing spirals always twist contra-clockwise, and the outflowing clockwise. It is just the opposite in the southern hemisphere.

All this seems complicated, but it is made simple and easy by a model. Take a sheet of Bristol board and draw on it a circle with a radius of six inches. Make a pinhole through it at the center, and cut the circle out. Then mark one side "Among the Clouds," and draw on it as many gently spiral curves sweeping toward the right as you may care to make, scattering them uniformly around the center and putting an arrowhead on the outer end of each.

Now turn the circle over, and on the other side write "Among Men," and on it draw inflowing, sweeping spirals, contra-clockwise or toward the left, and put an arrowhead on the inner end of each. Then imagine the upflowing winds to rise at and near the center through the tissue of the card.

In such a model one has the image of a cyclone in its natural proportions, or nearly so. If made out of paper, taking two hundred sheets to pile up an inch in depth, the radius should be an inch and a quarter, but if of inch boards the radius would be twenty feet. Such a whirl in the air is a thin disk about five hundred times as broad as deep. The model could be made a little more complete by drawing on it across the center a heavy straight arrow to indicate the direction of motion, and then trimming down the rear margin a little.

A general criticism of the model is that its margins are too well defined. In Nature the best developed part of a cyclone is the center. As one passes out from that the vortex gradually becomes less distinct.

So far as the winds are concerned, then, a cyclone is a thin disk of air, about a thousand miles in diameter and a couple of miles thick, lying on the earth's surface. Within this space the air flows in along the ground, up around the center and out above, and always with a spiral twist.

CHAPTER XIV.

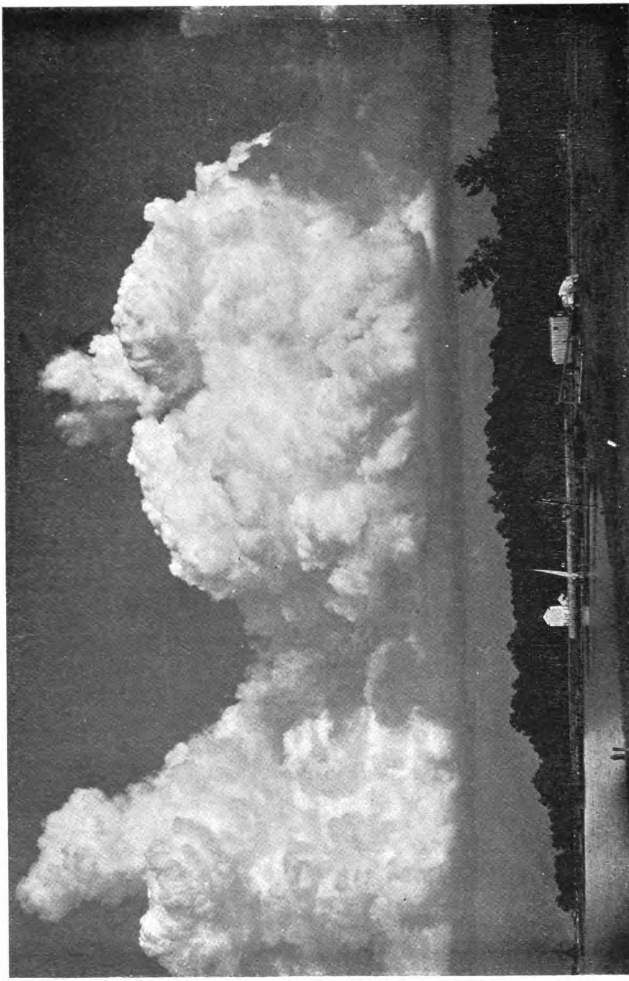
THE CYCLONE AS A STEAM ENGINE.

THE air which flows into the cyclone must be more or less moist. The more moist it is the more intense or violent will be the storm. If the air is nearly dry, the whirl will weaken and soon disappear. It is the moisture that makes it active and keeps it going.

The temperature generally lowers as one ascends. If the temperature at the earth is at the dew-point, as soon as the air begins to ascend the moisture will begin to condense, and fog will be the result. If the temperature at the earth is above the dew-point, then there is a layer above it somewhere which is at the dew-point of the surface air. When the air rises it must sooner or later reach this layer, and when it does so, condensation will begin. This layer will then form the lower surface of a cloud.

When the rising air begins to condense its moisture the latter gives out heat, and this warms it up a little. This is not enough to evaporate the droplets again, but it is enough to make the air warmer, and therefore cause it to rise higher. The rising cools it again, and this condenses some more of its moisture, warming the air, causing it to rise, and repeating the steps of the process just described. And this process is repeated as long as there is enough moisture to condense, or the movement of the air is still upward. It thus continues and extends the rise of the air, and makes clouds larger, not only at the dew-point, but for some distance above it.

This process can be seen occasionally over a pond or a wet swamp on a hot, calm summer afternoon. The moisture is itself lighter than dry air. Besides, it catches more of the heat in the sun's rays, so that moist air warms up faster than dry. Hence the air over a moist place on a clear, calm, hot afternoon soon becomes warmer and lighter than the surrounding air, and rises. When it reaches its dew-point layer above, it begins to form a pure white cumulus cloud, and this is likely to grow above until it takes the form of a hill or craggy mountain—flat below, rounded or peaked above, with projections here and there, especially toward the top. With an opera glass or small



From a photograph by A. J. Henry.

FIG. 27.—Double-turreted cumulus cloud.

telescope its process of growth can be seen and is very curious, often including sudden bulgings and outbursts.

The whole phenomenon is a column of rising air capped by a small cloud—a small, slender cyclone, stationary, and of a very simple and gentle sort. The column is invisible; nothing of it can be seen but the upper end, as defined by the cap of cloud.

As the sun goes toward its setting and the cool of the evening comes on, the upward motion of the air is checked and finally ceases. The cloud gradually fades away and disappears. If the wind rises, the column is broken and the cloud promptly disappears.

When the air is unusually moist and the weather hot and calm, such columns may form almost anywhere. Then a good many of these cumuli may be seen—small and scattered, like fleeces of sheep in appearance, resting lazily or drifting gently in a common direction, with some slight general motion of the air. If these cumuli grow during the day, it shows that the air remains moist, or is getting more so, and rain is likely to follow. If they slowly decrease in size and fade away, the air is getting drier and no rain will follow. These cloudlets have long been used as a weather sign.

The effect of the moisture is to make the cyclone continue and grow. Moisture is cool steam, and in continuing the cyclone it does its work quite as truly as hot steam does in the steam engine. Hence the cyclone is, in a true sense, a steam engine, and the parallelism between it and an ordinary steam engine may be carried out in many of the details. The furnace for this natural steam engine is the sun, for it furnishes the heat which evaporates the water and forms that state of steam which we call moisture or the humidity of the air. This furnace runs in common all the cyclones on the earth at any time—and there are many, perhaps a dozen or a score. The boiler is the surface of the earth, where the evaporation goes on. The conductor for the moisture is the atmosphere, which carries it off to the place where it is condensed. More precisely, the conductor for a cyclone is the column of rising air near its center. The condenser is in the cloud layer, and it is here that the energy of the moisture is applied. The work is that of making the air rise and of continuing the cyclone.

The cloud cap of a cyclone is a very interesting structure. Its form, as seen from the side, is shown in Fig. 28, where the great arrow *A* shows the direction in which it is moving.

The height of the cyclone as compared with the breadth is, of course, very much exaggerated, and the upper surface of the cap is not known as a whole. Hence the diagram is closed above with a dotted line. The dotted arrow lines below indicate the invisible inflowing and upflowing air currents.

The advancing edge of the cloud cap is cirrus and cirro-stratus, and is very thin. It ex-

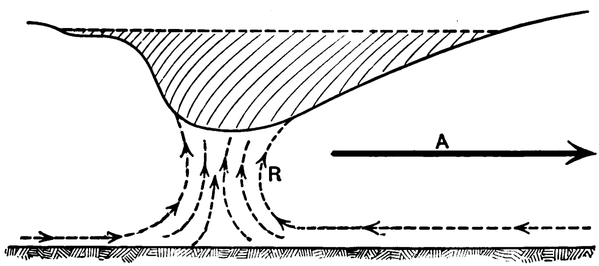


FIG. 28.—Section of a cyclone at the center and through the axis, showing the cloud cap, the inflowing winds, *R*, and the direction of motion, *A*. Note that the cloud extends farther in front than to the rear.

tends out a day or two in advance of the center, and may be seen thrusting up its long pinions in the west long before there is any other indication of the approaching low except by the barometer. Farther back the cirrus sinks and passes gradually into the heavy and denser forms of the center—compacted cumuli, from the bases of which rain may fall.

The change in cloudiness behind the center is in reverse order, but is more rapid. The outer cirrus is much higher than the other clouds, and the lowest cloud is at the center. If we could see an entire low at one glance, the side view would be curiously like a broad, very flat toadstool, of which the stem would be the column of ascending winds.

The rain comes on near the center of the cyclone, but rather in front than behind. In the diagram it would be from the clouds above *R*. At this point the rain would be heaviest, and might come down in torrents. Around this it would be lighter, and generally at no great distance light and gentle. It extends farther in front than to the rear. Snow falls more generally from the under surface of a cyclone cap than does rain, and about the *R* the flakes are larger and softer.

All these features vary with the intensity of the storm, and the more the moisture and the greater the heat the greater the storm. A common, fairly developed cyclone gives cloudiness for three days or so, fresh wind and rain for several hours. Many cyclones pass over which give only gentle airs and light rains. A few have no rain, and some but little cloud. Very rarely an intense cyclone, a hurricane, gives violent winds, dense cloud, and torrential rain.

CHAPTER XV.

CYCLONES TRAVEL EASTWARD.

THE way cyclones begin is not well known. Sometimes they start up in a region of even pressure and great heat covering a large territory. This corresponds to the little pond cumulus mentioned in the last chapter. The theory is that the warming of the air goes on for some days until something starts an uprush; this then goes on of itself on a grand scale, and the cyclone begins. This mode of origin occurs oftenest on the ocean and in the tropics. Perhaps the tropical hurricanes originate in this way.

Another way may be when a large land area is covered with moist air and becomes heated. Then trees, rocks, buildings, any projections capable of warming up the air in contact with them, start a series of small rising currents, each capped with cloud, and the conditions are those of the fleecy signs of rain of the last chapter. If the rising air increases, and the clouds grow, one, because of favoring circumstances, finally becomes larger than the rest, controls them, and in the end absorbs them by drawing in the air that fed them. This larger one becomes the cyclone which, no longer content with its birthplace, starts off on its eastward journey to its final destruction in the high north or over some great arid expanse.

New lows are also sometimes formed from the remains of old ones, and even the anti cyclones, or downpours of air, sometimes favor the formation of cyclones; and the tumultuous rush of the anti-trade winds high up in the air may sometimes aid. But the complete account of the birth of a genuine cyclone has not yet been made out. Though cyclones often spring into existence before our eyes on the weather map, we can as yet do little but suggest some of the conditions which may aid the process.

Once formed, the cyclone, if in the temperate zones, starts on a journey eastward. The ordinary paths in North America lie across the Northern States, but there are many variations in the path, and these are fairly uniform in themselves. They may be taken as branches of the principal path, and as such they are represented on the map.

The main traveled road of the cyclone centers is *A*. It passes directly from the Great Lakes to the Atlantic over Michigan, Ontario, New York, and New England; that is, the centers on the average take this path, while the storm itself extends to a long distance to the north and to the south. The

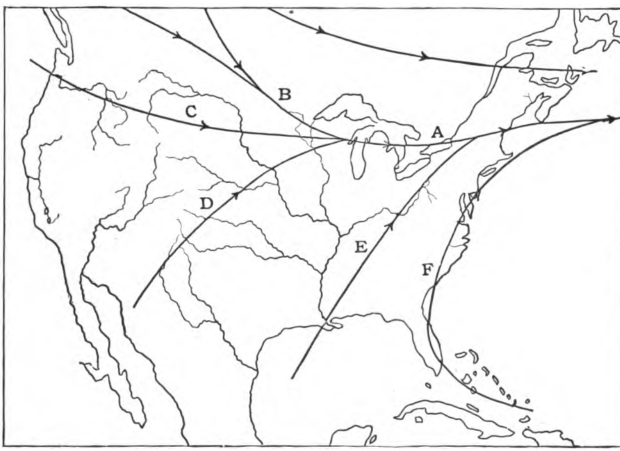


FIG. 29.—The course of a cyclone across the United States of America.

branch from the north is a very common one, and is itself branched above *B*. The path of storms in the wild and mountainous regions west of this branch is not well known, but it is probable that the most of the lows cross the mountains instead of coming down from the polar regions along their eastern slope. The branch *C* is that on which storms come directly from the Pacific. These are not very common, and are shut off completely during the long dry summer of that coast. The storms of path *D* are generally not strong, nor are they numerous on any of the southern branches.

Those of branch *E* are rare, but bring soft, mild weather even in the cooler seasons. The path *F* is that of the hurricanes of the West Indies which come on only in the autumn months; they sometimes dip farther to the west, as did the disastrous Galveston storm of September, 1900.

There is also a considerable number of storms which affect our northern border, while the centers remain in Canadian territory.

These are the average or customary paths of storms affecting the United States. Many cyclones originate in the States, but wherever they start they are likely to move at once so as to join the caravan on the regular routes. And, in general, a cyclone which is abnormal in its path is exceptional in its weather. It may move out because of unusual strength, and in that case it is much more severe. Or it may leave the customary paths because the forces joining to make it are weak or ill assorted, and in this case it is weak and soon dies.

The cyclone usually takes about five days to go from the Pacific to the Atlantic coast—a speed rather less than that of an express train. Indeed, the train east from Seattle or Tacoma would outrun the storm by a day or two in coming into Boston. General storms are often a little delayed by mountain ranges, and they hasten a little as they approach the Great Lakes or the Atlantic Ocean. It is interesting to note how the cyclones direct their course to the Great Lakes when they rise to the westward of them. This is probably because these lakes furnish them with the moisture needed to keep them going. The same thing applies to their approach to the Atlantic; but this leaves unexplained the fact that they leave the warmer Pacific Ocean or the Gulf of Mexico.

The general storms that pass on to the Atlantic are not lost there. They are felt, sometimes, in a very boisterous way by steamers crossing the Atlantic to and from Europe. The most direct and the usual route of the great transatlantic passenger steamers is along the usual route of the storms for the most of its length.

The Atlantic storms generally swing north, and, following the Gulf Stream, disappear in high latitudes, often to the north of Scandinavia. A few take a more southern route and reach the shores of Europe, from France to Scotland. The European general storms usually come from farther south, and have never been in the United States. They come up from lati-

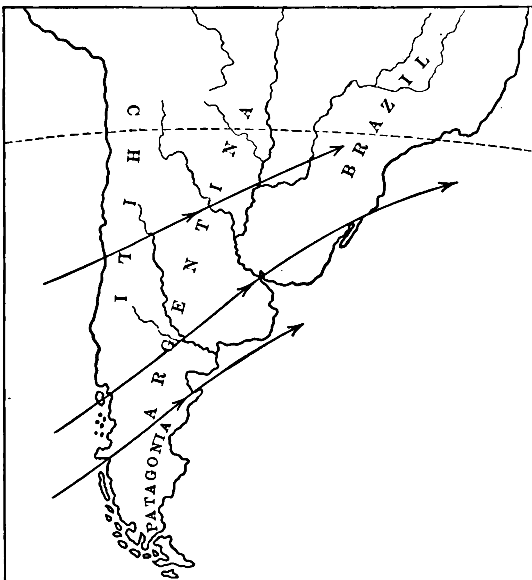


FIG. 30.—The way general storms cross South America.

tudes on the eastern Atlantic—on paths corresponding, perhaps, to the *D*, *E*, and *F* paths of the United States.

In South America the general storms strike the Chilian coast, especially the southern or

Patagonian part. They then pass northeastward and disappear on the Atlantic from Rio Janeiro to Buenos Ayres. The arrangement there is a close counterpart to that of North America, except as it is changed by the difference in the form and breadth of the continent. General storms are also common in Australasia, passing eastward, generally to the south of Australia.

Cyclones last several days, sometimes as long as a fortnight. The most of the American ones disappear in high latitudes over the North Atlantic or polar ocean when the temperatures are too low to keep up the necessary supply of moisture. The process of dying consists in the slowing up of the ascending current, the rise of the barometer, the disappearance of the cloud cap, and the slowing of the motion forward. The cyclones which cross Europe disappear over the dry plains of Russia and Siberia. This is due not to the cold, but to the dryness.

Over the United States cyclones usually succeed in reaching the Atlantic, though sometimes the low fills up and disappears within the range of the weather map. Many local and special reasons are given for this, but none of general significance. The energy of the low is sometimes exhausted even when there seems to be plenty of fuel for it in the form of sunshine, and plenty of energy in a high humidity. On the other hand, it sometimes persists over regions that are half desert, and the intensity of some winter storms shows that a high temperature is not always necessary. In fact, our knowledge of the history of cyclones, of their origin and destruction especially, is very incomplete, and the coming generation may find abundance to do in questioning these instruments of Nature.

Between the place where they begin and where they end they invariably, in the temperate zones, describe a long path to the eastward. Many theories have been proposed to account for this motion, but there are only two which appear to be based on efficient causes.

The first attributes the eastward motion to the rotation of the earth. This is known to give rise to a drift westward near the equator, and eastward in the temperate zones. The way in which it works will be examined in Chapter XVII. Here it is enough to note that the effect is more marked at some distance above the earth, and can be plainly seen in the clouds. A cyclone extends a mile or two up into the free air, and would therefore be submitted to this eastward drift, and more strongly at the upper end of its axis. An indication that this is the case appears in the fact that the axis of a cyclone is usually at a slant, and the upper end is directed eastward.

This is the case when the cyclone is carried along on the upper drift, while the lower end is dragged along the earth. Mountains, hills, forests, even those artificial roughnesses called cities, all exert a friction on the air currents passing over them; they serve as a brake to the motion and hold the air back.

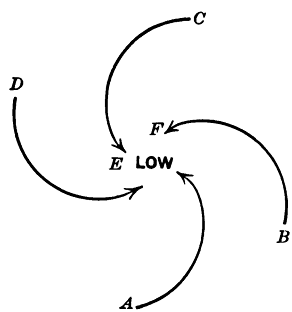


FIG. 31.—To show how the cyclones or general storms advance. The center is at first at *E* but is transferred gradually to *F*, then to a point farther east, and so on.

A second efficient cause for the eastward motion of cyclones is to be found in the way these whirls are perpetuated. We have already seen that this is by the condensation of moisture. Now, in the northern hemisphere the warmest, and hence the moistest, winds start from farthest south. These are the winds *A* in the diagram (Fig. 31). Those from the east (*B*) would be next in order of temperature and humidity. Then would come those from the north (*C*), and last those from the west.

The winds from the south curve around and actually enter the area of rising currents on the eastern side, and the greatest activity in condensation is where they rise. This makes a new center of the cyclone to the eastward of the old, or the center is transferred from *E* in the diagram to some point, *F*, to the eastward of it. The cyclone is then east of where it was, or it has progressed eastward. When established at *F* the warmest and moistest portions of the atmosphere pour in and up just in front of that, making a new center, and a corresponding new advance to the eastward. This process is repeated as long as the *A* currents of air are warmer and moister; though, for ease in explaining, I have spoken of the progress of the cyclone as a series of steps, it is really continuous.

Besides the motion eastward, the cyclone also has some north and south motion. It rarely follows a parallel of latitude, but generally has a strong northward or southward element in its progress, and each is over a certain territory; that is, all drift is northward in one region and southward in another. The sidewise drift depends on variations in the motions of the upper air, and this is somewhat affected by mountain ranges, plains, and oceans.

It also depends on the way the warmer and moister air enters the cyclone. In Fig. 31, *F* is a little to the north of *E*, because the spiral brings the inflowing currents, *A*, around to that point before they rise. The progress of the cyclone is then a little north of east. If the spiral *A* were less steep, *F* would be farther south, and the motion might be east or south of east. If the spiral were steeper, *F* would be carried still farther to the north, and the progress would be northeast, or even more northerly than that. In general, the more intense the storm, the more likely it is to turn toward the poles.

Combining all these features together, the picture the reader is to form in his mind is that of a series of great whirls in the air in the temperate zones, all sliding rapidly eastward over the earth's surface, with a tendency sometimes toward the equator, but more often toward the poles. Each one lasts several days. They pass over us at intervals of a few days, and this keeps everything stirred up and ventilated.

CHAPTER XVI.

THE WEATHER BROUGHT BY THE CYCLONE.

WE will now trace out the weather brought by the cyclone and the succession of the changes experienced by an observer as the great whirl or vortex drifts past his station. It will take the whirl several days to pass, the time it requires to do this depending on its size and speed. An ordinary gentle general storm affects the weather for four or five days, and controls it for three or four.

The first change is in the barometer and in the clouds. The barometer falls, first slowly, then more rapidly. With a fall of a quarter of an inch the clouds, appearing first in the west, have generally reached the zenith; at about three fourths of an inch the rain comes on. The barometer continues to fall during the rain, and does not stand still until the heaviest part of the storm is past. Then it begins to rise, and the rise is more rapid than the fall. Such is the succession when the storm passes centrally over the observer. If it passes to the north or to the south the change in the barometer is of the same character, but less in amount. The reader can perhaps picture these changes better if he marks on his cyclone model, already made, the successive isobars, and then causes the model to move slowly over some point on a map.

The storm tends to cut off extremes of temperature; it makes the day cooler and the night warmer than they usually are in clear weather, and the average temperature a little higher. As the cyclone comes on, the temperature rises gradually until about the center of the rain area. As the center passes the temperature again falls, and the fall is more rapid than the rise. The place of greatest warmth is a little in advance of the place of lowest pressure. The temperature after the storm has passed is usually lower than when the storm was coming on. This is because the air in the rear of a storm has come down from the north.

The succession of winds is the most curious and interesting of all the phenomena of the passage eastward of a general storm. If the reader will transfer to a transparent sheet (a piece of isinglass or a sheet of gelatin, or of tracing or oiled paper) the scheme of surface winds on his model, and pass this over the station according to directions, he will get a much clearer idea of the succession of winds we are now to explain.

As the cyclone passes over the station, the winds will change direction (haul, or veer, or back), and there will be three different cases, according to the direction in which the center

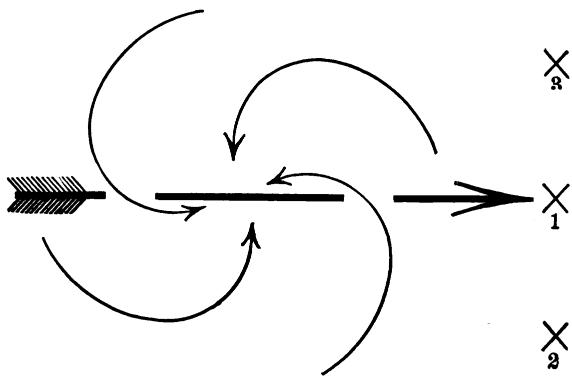


Fig. 32.—The succession of winds as a general storm passes over us. If we are at ×1 it reverses; if at ×2 it veers; if at ×3 it backs.

of the cyclone passes over the station, or to the south, or to the north of it. The three cases are marked on Fig. 32.

Case 1.—The cyclone passes centrally over the station of the observer. Let the great arrow in the diagram represent the direction of motion of the cyclone, and the cross marked 1 the place occupied by the observer. Then, if the system of winds is imagined to pass gradually over station 1, it will have first a gentle southerly wind; this will gradually change to a stronger southeasterly, then to a stronger easterly wind; when the center is over the station this wind will cease; there will be a calm while the rain descends and the center passes over; then there will suddenly come a strong wind from the west, followed by lighter northwesterly and then gentle northerly airs. With these the cyclone is past and the storm ends. The noteworthy feature in this case is that the wind abruptly and completely changes its direction, with a more or less long interval of calm between. In violent storms this abrupt change in direction of the prevailing wind, unless it is expected and preparations made for it, is very dangerous to shipping. The central calm in hurricanes is known as the eye of the storm. It is especially noteworthy, because while the sea is very rough there is no wind to steady the ship.

CASE 2.—The center passes to the north of the observer. Here the wind starts in from the southeast and then changes gradually through the south, southwest, and west, ending in the northwest. To the observer it gradually shifts through about half of the points of the compass. In making these changes it passes from east through the south to the west, or follows the sun in his diurnal course. A shift of wind with the sun is called veering, so that in Case 2 the rule is that the wind veers.

Case 3.—The center passes to the south of the observer. The wind here starts in from the east and changes through the northeast and north to the northwest. Here the change in direction is from the east through the north to the west, or against the sun. This is called the backing of the wind, and the rule for Case 3 is that the wind backs while the storm is passing.

From a consideration of these cases we may easily deduce a rule for predicting the weather as a low comes on. It is this: If the wind veers, the storm center will pass to the north, and if it backs, to the south. When we know the course of the center it is possible to give greater precision to the prediction of the details of the coming weather.

By studying the directions of the inflowing currents of air in a cyclone, as in Fig. 32, we may deduce a general rule for telling the direction of the storm center from the observer at any time. This, in many cases, is important—especially for seamen in heavy storms, for it enables them to lay their course away from the storm. Otherwise they might be running into rather than out of it. The rule was first drawn up by an eminent Dutch scientist, and is therefore called after him—Buys-Ballot's law. It is:

Stand with your back to the wind, and, in the northern hemisphere, the storm center is in front of you and toward the left hand.

The succession of clouds and occurrence of rain or snow have already been noticed. The clouds begin in high, thin curves, gradually thicken and descend, and become thickest and lowest near the center. They disappear in the reverse order. The clouds come on in about twice the time in which they disappear, and in the rear they are more likely to be broken up with patches of clear sky between them. The westerly and northerly winds that follow the storm center are well known as clearing winds, while the easterly and southerly are clouding ones.

Rain is heaviest just in front of the place of lowest barometer, and it comes to an end more abruptly than it begins. Snow generally extends farther out on all sides from the point of heaviest precipitation, and in cool weather the rain in front is likely to change to snow in the rear.

Moisture increases as the storm comes on. It often has a bad effect on people who are not quite well, especially on those subject to toothache, neuralgia, or rheumatism. They will begin to feel their pains a day or so before the center of the storm comes on.

The weather of a brewing storm is depressing, that of a clearing storm tonic. Even animals seem oppressed and disturbed by the increasing moisture. They appear troubled at the prospect of a storm, but become more cheerful and gay when the storm has passed. The increasing moisture tightens the joints of furniture, and makes windows stick and doors creak. The ascending air draws the gases out of drains, and the heavy air from the soil, causing bad smells.

Details differ greatly with the intensity of the storm. In an intense storm everything is more regular and symmetrical. The depression of the barometer is deeper, the temperature is higher, the clouds denser and with more motion among them. Especially the spirals of the wind are stiffened and become steeper, carrying inflowing air farther around before it can center and rise. The feeling of oppressiveness also is heightened, and in an approaching hurricane becomes so great as to be painful.

CHAPTER XVII.

EFFECTS OF THE EARTH'S ROTATION.

THE mechanical effects of the earth's rotation on its axis is the chief guiding influence to air in motion. A complete analysis of its effects requires special knowledge of mechanics of a sort possessed only by students of such subjects. It is abstruse and difficult. Only the general results can be here given and illustrated.

The first question that arises is this: Does the air fully take on the earth's motion of rotation, or, because of its soft and yielding nature, does it tend to fall behind the earth as the water on the turning grindstone goes slower than the stone, and so has a motion backward? Observation shows that the first is the case; the air has taken up the motion of the earth and moves with it quite as evenly and perfectly as do the oceans or the solid crust. And this will continue so long as the earth's motion is uniform and the air is at rest relative to it.

If the earth should begin to turn slower or faster, then there would be a motion in the air until it had settled down to the new motion of the earth. Such changes do not take place, or, if they do, it is with extreme slowness. Thus the rotation of the earth does not cause motion in air at rest. It is only when air moves that the earth's rotation affects it.

This is the case whatever way the air moves, whether vertically or horizontally. What is true of air in motion is true of all other motions and can be applied to anything. If a stone is dropped down the shaft of a deep mine or from the top of a high tower, it will fall not exactly under the spot from which it was dropped, but a little to the east. This is because the top of the tower is moving through a greater circle, and hence faster. For anything moving upward the result is the reverse, except that it is affected by the friction of the air. In any case the effect in vertical motion is slight, and in problems of the weather it can be neglected.

The important case is that of a body moving horizontally—that is, along the earth's surface or parallel to it. The effect is then so considerable as to be seen in many kinds of motion. It is a guiding principle which directs to some degree the motions of waters on the earth, and really controls the great motions of the atmosphere as to the direction they must take. The effect may be stated in a simple rule which is of great interest and importance. It is this:

In the case of any body in horizontal motion, the rotation of the earth causes a divergence toward the right in the northern and toward the left in the southern hemisphere.

This is for an observer who stands looking in the direction in which the body is moving when it moves away from him; the greater the deviation the greater the velocity. It also increases with the latitude. It is greatest at the poles and nothing at the equator.

The best illustration of this deviating or guiding influence is given by a pendulum hung free to turn as well as to swing. If such a pendulum is set swinging, it will be found to move with each swing toward the right—or in a clockwise direction—and this it will keep up as long as it swings. At the pole it would complete the circle in twenty-four hours. In the latitude of New York it would take it about thirty-seven hours. The time increases as we pass from pole to equator. This is called the Foucault pendulum. It is easily made and tried. To make the deviation plainly visible the pendulum should be at least thirty feet long.

The deviation can be detected in the case of any rapidly moving body when the motion is of such a sort that it admits of minute and precise observation. Cannon balls deviate appreciably to the right, and railway trains show a strong tendency, when they leave the track, to do so on the right-hand side. Streams are more likely to eat out the right-hand bank than the left. In the great rivers of Siberia, flowing for hundreds of miles through open plains in high latitudes, the right-hand banks are usually steep, and are so continuously eaten away by the water that in many cases village sites must be moved back. On the other hand, the left banks are low and flat—plains over which the river has in the course of centuries shifted farther and farther toward the right.

The effect of the earth's rotation is shown still more distinctly in the great ocean currents. Each ocean in each hemisphere is practically one great whirl in very slow motion. So far as the confining shores permit, the divergence of the currents making these whirls is in accordance with the rule just laid down as to the effects of the earth's rotation. A similar though still slower whirl exists in each of the Great Lakes.

The air over the earth's surface, except in high latitudes, is in a great double vortex, one for each hemisphere. The air along the equator rises because of the heat of the sun; pours in along the ocean surface, making the trade winds, and out above in these winds of the upper air called the anti-trades. Each vortex makes a great ring around the earth, and controls these currents of air which help to make the eastward drift of cyclones. The trades deviate toward the west on account of the rotation of the earth and in accordance with the rule, and for the same reason the anti-trades toward the east.

The ocean surfaces in each hemisphere are occupied by a series of almost stationary centers of high and low pressure, already mentioned, and the winds about these show to a marked degree the same influence.

It now remains to show how this guiding influence of the earth's rotation gives to cyclones their contra-clockwise rotation. Let us suppose that *C* in the diagram is the center of a cyclone where the air is ascending, and that *P* is a particle of air a long distance off. It feels the suction effect of the rising at *C* and tends to pass along the arrow *P C*. It would do so if let alone, but in comes the controlling power of the great turn of the earth and twists it out of its course toward the right. That brings it in an hour to the point 1. Now it tends to pass in along the arrow 1 *C*, but it is twisted again toward the right, and arrives at 2, and so on through the points 3, 4, 5. And when it gets in to the center, if it could look back over its course it would find that, instead of going straight toward its center, it had followed a curved path marked by *P* 1, 2, 3, 4, 5. And this curve is the contra-clockwise spiral so important in northern weather. In southern weather the twist would be to the left, and the result would be a clockwise spiral.

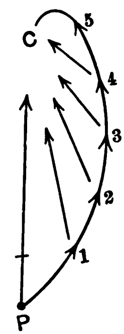


FIG. 33.—The way a particle of air is caused to take a contra-clockwise spiral in entering a cyclone.

CHAPTER XVIII.

ANTICYCLONES, OR HIGHS.

CORRESPONDING to the centers or low pressure of cyclones on the weather map is a series of centers of high pressure, or anticyclones. They are so called because they are the opposite of the cyclones in having a downward motion of the air while the latter have an upward motion. In other respects they are contrasted, though not in all cases direct opposites. That in the anticyclone the air descends is shown by the fact that it flows out in all directions from the base, and this outflow could only be kept up by a supply from above. The outflow is gentle in most cases, and so must the downfall be. There are a few cases in which the air seems to descend like a cataract, for in these cases it is bitterly cold, and the air flows off in a strong wind. Such is the case of the blizzard, to be discussed hereafter. The downflow generally is so gentle that it is but a gradual sinking.

Another way of knowing that this is a downflow of air is by the higher barometer. A mass of air descending will cause a pressure due to its weight, and also an addition due to its motion downward. These two effects will be added together in the way the barometer is affected, and will make a higher pressure than usual. In the same way a mass of air ascending will make a pressure due to its weight less the effect of its rising, and this will make an effect on the barometer less than the average. Steady and continued changes in the barometer must be due to such causes.

The air pressure over a high, or anticyclone, is fairly uniform for a large area. The space covered by an anticyclone is nearly always larger than that covered by a cyclone, and the pressure is nearly the same throughout. It is often higher above the average pressure than the cyclones are below it.

The relation to the temperature is more complicated than in the cyclone. The descending air is of course colder, for it comes from the colder regions above—the regions that give the cold to high mountain tops. At the same time clouds are absent, and there is no such protection from the sun's rays in the daytime nor from loss of heat to the sky—which is always so cold that when clear it will take up all the heat that is sent to it. The result is that the nights are decidedly colder in anti-cyclonic than in cyclonic weather, and the days are decidedly hotter. The weather on the whole is colder, sometimes very much colder; but the contrast between day and night is also very much greater. So far as the temperature is concerned, this weather is not so easy to bear as the cyclonic weather.

The winds are usually very gentle, often hardly appreciable, especially near the center of the area. Farther out a system of winds can be traced which are out-flowing and are gently spiral. They are clockwise and correspond to the upper winds in a cyclone. So far as the winds are concerned, the anticyclone may be looked on as a large and gentle cyclone turned upside down. The curvature of the outflowing winds is sometimes scarcely perceptible. As a whole, and in general, the high is a calm area, or with light winds only.

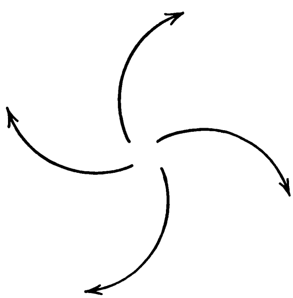


Fig. 34.—Scheme of outflowing winds from a high. They are less curved than the winds flowing into a low.

The air of the anticyclone is generally dry; that is, drier than the average air. The relative humidity is low. This is because the air has settled down from above where the humidity is small, and it can not be large because of the coldness there. In settling down it has forced its way into denser air. Now, the condensation of a gas always makes it warmer. Advantage can be taken of this to light a piece of punk in a tube in which a rapid condensation of dry air is effected by driving in a piston. Probably some ingenious person will some day make an everlasting match, without the use of the dangerous phosphorus, in this way.

In the case of the anticyclone the air as it settles down becomes gradually denser, and hence warmer, and the humidity, low at first, becomes still lower. Clouds, of course, can not be formed under these conditions, and the great anticyclone is clear and sunny or lighted by the stars. There can also be no rain or snow, and so the anticyclone adds nothing to the natural water of the area over which it passes or stands. Its dryness makes it rather increase the evaporation, and so tends to aridity.

We have just spoken of the standing of the high. It has an eastward movement, as has the low, but in the former it is slower and more uncertain, and less definite in its path. Besides, it is likely to make halts at favorite places, sometimes for days together and occasionally for weeks. One of its favorite halting places is over the valley of the Cumberland and surrounding regions, and here it may stay for a month or two. Another is over the great interior basin of the West—Utah and Nevada. The anticyclones are inclined to run to the south of the cyclone paths. They usually come on from the West to the lower Ohio valley, and from there pass a little to the south, leaving the coast near Cape Hatteras.

The weather of a high or anticyclone can easily be guessed from that which precedes it. It is calm and clear, hot in the day and cold at night, likely to be frosty, dry, and somewhat trying. At the same time the air is very pure and bracing. It makes the calm and sunny weather which everyone prizes, when it does not last too long. It also makes the weather of the long-continued drought so injurious to the farmer. The untimely and destructive frosts of late spring and early summer are almost invariably anticyclonic. The rapid passage of an anticyclone to cyclonic weather is a welcome change. The long delay of an anticyclone over any place brings drought, nervousness, and distress. The cyclone brings cloud and storm, but it also brings the welcome rain and keeps the air well ventilated and sweet. The anticyclone brings bright, sunny, tonic weather; but this degenerates into dry, stagnant, dusty days, and dry and frosty nights, if it lingers too long.

When the anticyclone comes and stays in summer it brings a time in which sunstrokes occur, and the heat becomes intolerable, especially in great cities. In the country it may cool off at night, but in the city the thermometer remains high, because the pavements and walls of the buildings get so heated during the day that they give out heat all night. Germs of infection then develop and spread, the hospitals are full, and death reaps a rich harvest. Even in the country the springs dry up and the streams evaporate until they become thick with germs, and fevers and other diseases result. Such weather has been called a "sizzard"—a humorous modification, probably, of its opposite, blizzard. It may be defined as a period of high-pressure days about midsummer.

CHAPTER XIX.

BETWIXT-AND-BETWEEN WEATHER.

THOUGH the cyclone and anticyclone are the leaders in the procession of the weather eastward, they by no means embrace it all. The weather map of the United States has rarely more than two of each at any one time Quite frequently there is but one center of pressure, and not very infrequently none, or not a well-defined one, on the entire map. The weather, then, must be weather other than the cyclone or anticyclone—betwixt-and-between weather, intermediate weather. In the tropics this can hardly be called intermediate weather, for little of the cyclonic or anticyclonic occurs there, and that which is between cyclones here is there ordinary weather. As one passes north the centers of pressure become more and more common; at least over the North American continent, until a latitude of about 45°—halfway to the pole—is reached, when we find the maximum number. Above that they are fewer, at least to as high north as our knowledge extends. The "betwixt-and-between" weather is therefore the more common weather in the Southern States, and especially in Florida and in the Southwest. It is also more prevalent through the drier seasons of the year.

The most striking and noteworthy intermediate weather is when the great centers of pressure are so placed with reference to each other, or with reference to the irregularities of the earth's surface, or to the currents of air at some distance above the earth, that the one aids the other. The commonest case is that of the westerly gales which sometimes prevail over a large part of the States for two or three days together. They usually come on in the autumn or winter, but may prevail at other seasons of the year. These gales blow over an area several hundred miles across, and are so high as to be dangerous to shipping; those of the autumn are especially dangerous and destructive on the Great Lakes. Such gales usually originate through the coöperation of a low with a high which lies to the west of it. The higher winds above thus get a start for a sweep over the earth, and when this is once begun it is likely to die out with difficulty.

When an anticyclone lies to the north and

FIG. 35.—Texan norther advancing with head of clouds.

is just east of the Rocky Mountains, and especially when a cyclone lies to the south and east of the anticyclone, the conditions are favorable for conducting a polar wind far to the south. Thus arise the northers of Texas—high, cold winds which sweep down from the north with high velocity and a head of cloud, dust, and sand, suddenly changing the temperature in Texas from almost tropical to frigid. The norther can be seen coming from a long distance, and its approach greatly disturbs animal life. The fall of temperature is very rapid, and a high north wind replaces calm or gentle breezes from the south.

The norther occurs in winter, and is very much dreaded. It often extends down over the Gulf of Mexico, making tempestuous winds in the western part of that body of water. Sometimes it goes still farther, and, crossing the narrow part of southern Mexico and northern Central America, brings high, cool winds over to the Pacific Ocean, extending nearly to the equator. The norther is one of the most injurious features of weather over the western plains.

Intermediate weather may occur in other parts of the United States. The cold wave is an extension of the high toward the east and southeast. Otherwise it is like the norther, but the conditions for a flow of polar air toward the east or southeast are rarely so favorable as toward the south. Hence the change is generally not so fierce and the wind not so high. At the time of a cold wave a well-marked high stands in the northwest, east of the mountains, and conducts the cold upper and northern air down over the warmer areas. The sky clears, the wind is high, and the cold severe for the season of the year. Cold waves come on generally in autumn and winter, and may carry a frost or even a severe freeze down to the Gulf of Mexico, and in rare cases well over the peninsula of Florida. The wind lasts from one to three days, and then the high itself comes on, bringing calmer, clear, and still colder weather. This is the greatest weather misfortune that occurs to the Eastern, and especially to the Gulf States. The hurricane itself, which may affect the Atlantic coast to as far north as Nantucket, does not do such serious damage, and the damage it does is more easily repaired. The tornado is very limited in its destruction; besides, it does not extend so far east. The damage done by the cold wave in the South is chiefly that of freezing delicate plants. Orange groves subjected to this severe weather take years to recover.

One special form of the cold wave is fortunately almost always much more confined in its area. This is the blizzard. It is an unusually severely cold wave, during which the air is filled with fine snow driven before the high wind. This snow consists of minute sharp needles of ice, and is so abundant that it shuts off the view, and so irritating when it strikes the skin or is breathed that it soon produces death in those exposed to it—death frequently preceded by madness in man and animals. Such a tempest causes great destruction among cattle, and the only security from it is to have them housed before it begins. So distressing and bewildering is this storm that men have been known to get lost and perish in passing between the house and the barn. The blizzard is a winter storm, and rarely extends beyond the northwestern States east of the mountains.

Less understood, but probably due to similar causes, are the hot winds of spring and summer occurring in the central western regions from California to Kansas. In California they are northerly, in Kansas southerly. They come on suddenly, and are so hot that they actually scorch the growing crops and make burns on the exposed side of the fruit. The hot air apparently passes out of a high, intensely heated region over some extensive arid area—southern Idaho, on the one hand, and perhaps Arizona or New Mexico on the other. Such winds are of the same character as the sirocco of the western Mediterranean region.

From the nature of the case the great outflows of intermediate weather must come from the anticyclone, for it is the form from which the wind flows away. The intermediate weather of cyclones must depend on inflows or the results of disturbances on the margin of the great indraft of the low. There are many such inflows, and some of them are very important. They are generally themselves whirls, being due to the disturbance of a great whirl, but a few are apparently of different character. For instance, a sort of storm of rare occurrence is the ribbon storm, where a high wind runs in a narrow streak without appreciable whirl. These are called tornadoes, but they are not. They can be distinguished by the fact that the things overthrown by them are not thrown down in a spiral direction that can be recognized. Besides, there are likely to be several parallel ribbon storms at the same time and not far apart, a thing that could not happen with intense whirls like tornadoes any more than one could have several whirlpools close together in water.

There are also other rare and little-known forms. The air is capable of containing gusts and whirls of many sorts, light or intense, not only at the surface but at some distance above. Balloonists often meet narrow, limited winds above the earth's surface, and the confused movements of the clouds in breeding weather show how varied the motions of the air may be. The different forms have not yet been separated completely from each other; the separation is difficult because one form passes into the other. There are, however, a few forms so distinct and so interesting that they should receive separate treatment.

These come under the general head of local storms, as opposed to the general storms already described. They are small, last not many hours, and travel but a few miles. They bring the most of the rain in the tropics and in summer, and may be in connection with a cyclone or may not. With us a connection with the cyclone can be generally traced; in the Southern States this connection is rarer, and in the tropics very rare. They may be due even to local conditions, and their paths are, in the gentler forms, more or less controlled by the topography of the surface of the earth where they occur.

CHAPTER XX.

TORNADOES OR INTENSE LOCAL WHIRLS.

THE tornado is an intense whirl of small dimensions. The central destructive part is only a few rods wide, and the entire system of winds is probably only a mile or two across. It is a creature of a few hours only, and not of days or weeks like the cyclone. It is generally a sort of attendant of the cyclone, being developed in its outskirts. Hence it is called a secondary whirl, the cyclone itself being the primary.

The relations of tornado to cyclone are curious and interesting. The isobars about a cyclonic center are usually nearly circular, but they may take on any form as an exception, and Fig. 36 represents an occasional one. It has an extension southward, making a sort of trough. Drawing through it the line *A B* and passing it through the center *C*, then calling this line the critical axis of the cyclone, we may say: Tornadoes, when they form, are most likely to be made near the critical axis of a cyclone, and especially near its southern end.

To understand better the reason of this, let us sketch in the winds for such a cyclone. They appear as in the diagram of winds, and it appears that because of the stretching out of the isobars to the

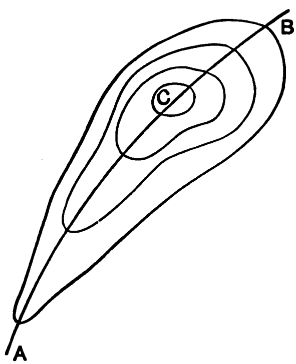


FIG. 36.—Low with extension southward. A trouble breeder. *A C B* is the critical line and *C* the center.

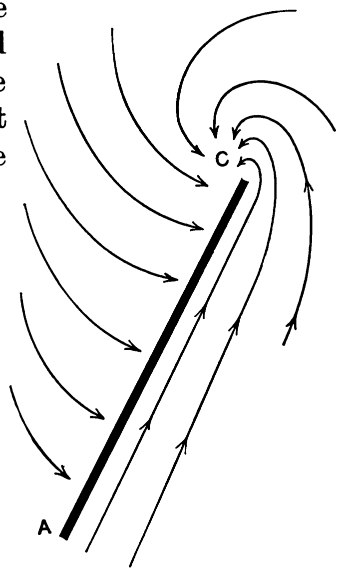


FIG. 37.—The winds of the trouble breeder. *A C* is the critical axis.

southward a remarkable condition of things exists along the critical axis south of the center. Here the southern air is drawn up in nearly straight lines toward the center, while the northwesterly air is drawn in to the cyclone in such a way as to meet the southerly winds at a right angle, or nearly so, and this will be along, or near, the critical axis *A C.*

A great deal of disturbance will be caused all along this axis. The cold, dry, northwesterly air will come in direct contact with the warm, moist, southerly air, and either shove it aside, mix up with it, shove under it, or pass above it. In any case, along this line and for a region on each side of it, particularly toward the east, there will be many local disturbances of the weather, among which may be thunderstorms, hailstorms, and tornadoes.

When the disturbance is intense a tornado may be formed, and this is most likely to occur in the warmer part of the day, when the sun also aids. To the onlooker there appears a great agitation in the clouds, especially to the west. Then a whirling motion is visible, and soon a great funnel-shaped extension is let down toward the earth. It is seen to be made of cloud in violent whirling motion, and is very similar to the funnels extended downward when waterspouts are formed, as described by sailors. The funnel is not steady, but swings back and forth. something like the trunk of an elephant. At first it does not reach the ground, and in some cases it never does, being withdrawn gradually before it attains such a length as to touch the earth. In these cases there are no destructive winds, but observers report hearing a roaring sound. The facts that the tornado funnel is gradually extended downward from the air, and that tornadoes may exist in the air and

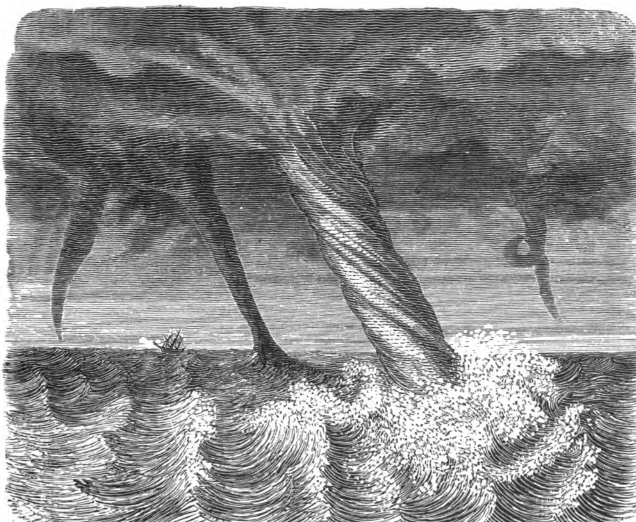


FIG. 38.—Waterspouts.

never reach the earth, indicate that their home is in the cloud layer.

If the funnel continues to extend downward, as is usually the case, it passes along, swinging from side to side and making occasional leaps from the ground. Meantime, wherever it touches it leaves death and destruction behind it. It takes it only a few seconds to pass any point, but after it has passed the place is hardly recognizable. One gentleman relates that he was sitting in his house at Viroqua, Wis., and his horse was secured in its stable some little distance away. A tornado came on them fairly unawares, and a few moments afterward he came to consciousness lying in his cellar, his house gone, his horse's head lying across him, and both pinned down by timbers and fragments of buildings from some distance around.

Fig. 39 is an actual photograph of a tornado. It is the one that visited Lake Gervais, Minnesota, on July 13, 1880. The photograph was taken at a distance of about six miles. The funnel can be seen through the rain that was falling between it and the photographer. This tornado was a severe one and was quite destructive. Photographs of tornadoes have several times been made. This appears to be the best and most typical, and apparently has been little touched up by the photographer.

The storm sweeps on in a general northeasterly path, and lasts but an hour or two. It is often accompanied by very remarkable electric phenomena, the air being heavily charged

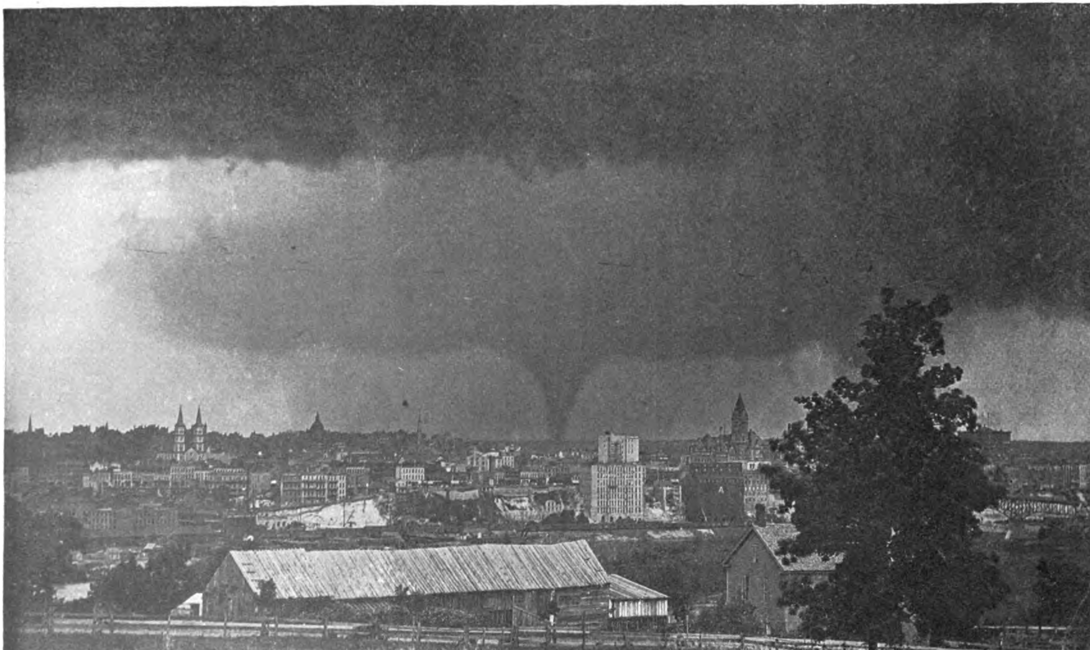


FIG. 39.—The Lake Gervais, Minnesota, tornado. This is a print from an actual photograph of the tornado that visited Gervais, Minn., on July 13, 1880. The photograph was taken at about a distance of six miles. The funnel can be seen through the rain that was falling between it and the photographer. This tornado was a severe and destructive one.

with electricity. Rain frequently follows the tornado and may be very heavy, sometimes so much so as to add materially to the damage done by the winds.

The winds are too violent and the storm too sudden and of too brief duration to permit observations to be taken of it with instruments; but the way things are thrown about can be examined after it passes. These, with the appearances of the storm, enable us to make out its structure with certainty. It is a whirl of small dimensions, but very violent in character. The air rises in whirls, which are nearly flat, about the center only, and the path of a particle of air or any small body taken up would be something like the coils of wire in a bedspring. The whirls are so violent that the center is composed of rarefied air only, and acts like a suction pump on things over which it passes.

It is to this suction, perhaps, are due some of the most mysterious results of a tornado. A building not broken up and scattered by the violence of the winds is apt to have its four walls fall out in four directions as if it had exploded. Ponds are sometimes sucked up and carried off, and even the surface of the ground along a narrow strip may be cleared away. In closed houses which were not injured light articles have sometimes been abstracted by the tornado and carried far away. This is well illustrated by a story told of a Tennessee cabin over which a light tornado passed one day. After it had passed by, the woman of the little household noticed a bright-colored ribbon hanging down from the fireplace. It was of the color of the ribbons on her much-prized bonnet, and she proceeded at once to investigate. She found it was indeed her bonnet caught on some projections of the mortar in the flue of the fireplace. The bandbox in which the bonnet was kept was found open. It appears that in this case the suction action of the storm was enough to open the closed bandbox to let out a gush of denser air that carried the bonnet with it until the latter was caught in the chimney. In another case a soldier's discharge paper is said to have gone the same way.

Now, to maintain a vacuum that will exercise so great a suction power the whirling must be indeed intense, and that it is so is plainly seen to be from its effects. It plucks the feathers from fowls, drives laths through small trees, and wrecks or twists the strongest structures around. In some cases the work it has done enables us to calculate the velocity of the wind which did it, and this has been found to amount to two hundred miles an hour. That means a pressure of two hundred pounds on each square foot of the sides of buildings.

Tornadoes may occur almost anywhere, but in the United States they are most common in the Mississippi Valley east of the great plains. They are fortunately not common, for they are very destructive. The area over which they work an injury is small, being a strip of territory rarely aggregating more than a square mile of surface. There is on record an average of fifty of them a year, a score of which have done injury of a serious character to the country over which they have passed. This would mean about twenty square miles affected each year, but the region in which they are likely to occur is a million and a quarter square miles in extent. The prospect that one may pass this year, or the next, over the particular square mile in which the reader is at this moment is therefore $\frac{1,250,000}{20}$, or one chance in 625,000. This chance is not worth worrying about.

Even if a tornado chanced to pass over a strip in which the reader might be, it would be far from certain death to him. Indeed, considering the amazing violence of these storms, it is remarkable that the deaths from them are not more numerous. It is only when they pass through populous cities—as Louisville and St. Louis—that the casualties from them are very numerous. The timid who live outside the tornado area worry to no purpose. Those who live in the region affected may calm themselves by the reflection that, taken altogether, there is not one chance in a million, though they lived to be centenarians, that they will be injured by a tornado.

CHAPTER XXI.

STORMS OF ICE, SLEET, BALL SNOW, AND HAIL.

THE storms of by far the most importance in the ice series of local storms are the hail-storms.

The proper ice storm is that which covers the ground, roofs, and the branches of trees with a thin layer of ice that make them glitter in the sun, giving a beauty to the leafless trees which seems quite foreign to them. The cold that here changes the water into ice is in the objects on which the rain falls. After a long winter cold, when everything is full of frost, a cyclone comes on with warmer weather from the south and lets fall a gentle rain on the yet ice-cold objects on the surface. As soon as the rain touches these it is chilled, and before it can run off it is changed to solid ice. If the objects are very cold and the rain continues some time, the branches and telegraph wires become so loaded with ice as to be brought down by their own weight. This is

Fig. 40.—The effects of an ice storm in Massachusetts.

an unusual storm; rarely more than one a year occurs, and sometimes several years together pass with none at all.

The next step in the series is sleet. It consists of snow loaded with liquid water. The snow crystals are doubtless formed in a cold, higher layer of air. In descending they pass through a very moist, warm layer, and the water is abundantly condensed on their surface. It may be also that the snow is in part melted. Sleet is common enough, occurring usually in the spring and autumn.

The next step to this is the snow proper. This is formed in the clouds and descends slowly with little whirling motions. The formation must be in gentle or calm weather when the flakes are large, and in any case the motion of the air at the place of formation must be slight. Otherwise the flakes would not be regular, and would be more or less broken and compacted by jostling together.

There may be additions to the flakes as they slowly descend through the air below the cloud layer. This is, in all probability, often the case with rain. As has been mentioned, the opposite condition with regard to rain may often be seen in dry climates; that is, rain will form in the clouds and be seen to descend, but will all disappear before it reaches the ground. It is evaporated again in passing through the dry air below.

The next grade is that curious fall of spring and autumn called ball snow. The elastic particles which come rattling to the ground, where they dance about for some time before they come to rest, are of the size of medium shot, and are white like snow, though they are so compact that they do not break in striking the sidewalk. They seem to be snowflakes which have been formed when there was intense motion, so that they were jostled together until they took on a rounded form. They are not frozen raindrops, for in that case they would be transparent. The clouds from which they fall show no signs of unusual activity, so we can only conclude that the whirls which gave them their form were above the clouds.

And here we are introduced to the idea that there are whirls among the clouds. There are not infrequently two, and sometimes more than two layers of clouds, the one above the other. We have found that the tornado is formed in the lower cloud layer from which it bores a way down toward the earth. We have also noted that the cloud layer is one of great activity. It may be added that the upper surface of a cloud must act toward the air above it much as the surface of the earth acts toward the air just above it. It is therefore probable that between two cloud layers there may be whirls as between the earth and the first cloud layer. Indeed, in one case at least, Wise, the balloonist, found a whirl between clouds, and was involved in it to his own great danger. Adopting the idea of whirls between clouds—extremely probable in itself, though they are rarely seen—the explanation of the mysterious hailstorms becomes much easier.

Hailstorms are hot-weather local storms characterized by the fall of hail, and usually by sharp lightning and thunder. They are most common in the daytime and in the hot season of the year. They rarely occur at night. They are most probable when the day is hot and dry, but the night gives an abundant dew. The cloud forms are first cirrus; then this sinks to cirro-stratus, and this still farther to a dark-gray storm cloud out of which the hail falls. The hail cloud shows a strong, heaving, boiling motion, and from its bottom often hang ragged fringes. It is a cloud in intense activity, but the cause of the motion is hidden from us. It is probably a strong whirl which remains above the cloud.

The approaching storm makes a curious crackling, rushing noise, due to the stones striking on each other. The stones are of various forms. The commonest are flat and shaped like a lens. Others are spherical, sometimes smooth, sometimes knobby. Still others have some of their sides flat and angular.

A common size for a hailstone is that of the pea, less often that of a large bean, sometimes that of a hen's egg. Still larger are sometimes recorded on good authority; and in Kansas, on August 15, 1883, one is said to have fallen which weighed eighty pounds.

The total amount that falls from a hail storm has been measured and estimated several times. In Switzerland in 1881 there was a hailstorm of only a few minutes' duration which let fall hail to the weight of a hundred tons. In 1788 a storm passed through France into the Netherlands, from which descended on the earth hailstones to a weight, estimated by a recognized authority, as aggregating four hundred thousand tons. That is a larger amount of ice than there is in some glaciers.

Hailstorms occur all over the earth, but are not so common at high elevations and in high as in low latitudes. They are very local in character, and show a strong inclination to avoid forests and mountains and to travel along valleys. They also show a tendency to come again to a place visited before; and of two places not far apart, one may be frequently visited and the other not at all.

The destructive effects of hail are great on buildings—windows especially suffer—on growing crops and vineyards, and on small animals. The destruction is so great that companies insuring against hail are not uncommon, particularly in the Old World. In this country such companies also generally insure against injury by tornadoes. There are also many who believe that hailstorms may be prevented by such simple means as planting tall poles or firing cannon.

The explanation of the formation of hail has already been suggested. It should be added that when hailstones are cut open they are often found to be in layers, and sometimes the nucleus is a little sphere of ball snow. The form of most hailstones is that which would be given them if they were set spinning in the air; the spinning might be caused by a strong whirl like a tornado, and this would also account for their being suspended in the air until they had grown to so large a size. We can think of nothing that would keep them in the air until they weighed from an ounce to many pounds, except the very strong rising winds of a whirl. Moreover, the layers into which they can be divided would indicate that they had passed through the whirl several times. When driven up once and thrown out above they must have been caught again in the whirl, and this must have been repeated as many times as they have layers. At last they would be thrown out in such a way as to escape the whirl and reach the earth.

CHAPTER XXII.

THUNDERSTORMS AND CLOUD-BURSTS.

THE local storms classed under the head of thunderstorms have a common feature in the strong electric condition shown by all of them. They are usually rather gentle, for when intense they pass into storms such as the tornadoes and hailstorms already described, or into a kind of storm marked by especially heavy local rainfall and called cloud-burst. Thunderstorms otherwise differ very much among themselves, and probably include a large number of different sorts of local storms.

For instance, they are found under three different conditions. The first kind are found along the critical line of a cyclone; it occurs in the same weather as the tornado, and may be quite intense. Indeed, in this class there is every grade of intensity, from the very gentle shower with some lightning, to well-marked whirls of such violence that they might be called tornadoes.

The second occur in troops or herds over regions sometimes as large as a State or two States, sometimes covering only a quarter of a State, or a less area. These regions may be in the southeast quarter of a cyclone or have no visible connection with general storms; they are most common in summer and in the tropics, and the region over which they are likely to crop out is apt to be one that has great warmth, little wind, and much moisture in the air. Here they begin to develop in the later morning hours, and travel eastward during the day, disappearing at night. They are usually many miles apart, and bring the light showers of haying and harvest time so common over the Central States. After a thunderstorm of this sort has passed, it appears to exhaust the capacity of the air for such storms. It is not apt to repeat itself for several days.

The third sort are solitary and more or less dependent on the features of the surface. They are likely to start up in valleys or at the base of high hills or mountains, and do not travel far. The weather in which they occur is much like that of the preceding.

All three kinds may have sharp lightning and thunder, and any one may become intense, though this is much more likely with the first than with the other two sorts. The third is the commonest in the tropics, where it shows a decided choice for certain localities. During favorable weather there, one is likely to form daily at the base of some favorite mountain. It will begin to form its cloud cap about noon. By four in the afternoon it will have developed a great black cloud in active movement, lightnings will begin to flash, the thunders to roll, and the rain to come down; then it will move nearer the mountain, the rains will increase, and the cloud shut out the declining sun. As it exhausts its rain it will move away and soon will begin to disappear. By ten o'clock at night it will probably be all gone, and the stars shining brightly without a cloud in the sky.

The weather in which thunderstorms occur is usually warm, the season the hot time of the year, and the hour the warm hours of the day; but there are exceptions, thunderstorms sometimes occuring even at the coldest time in the night. Winter thunderstorms are also known. Both these latter are generally stronger and more destructive than the others, and the winter storms are usually distinct whirls; at least this is the case along the Norwegian coast, where they have been studied by Mohn.

Thunderstorms are usually on the surface, or between that and the lower layer of clouds. In this case they bring a decided change of temperature with them. The air is cooler and the wind changes. A few seem to be in the upper air, and some even may permit a few hailstones to escape above. These are transition forms toward well-developed hailstorms.

In the case of the cloud-burst there is little on the surface of the earth to show that immense quantities of water are confined above. The clouds are dark gray or black, and are in active turmoil. Lightning strikes through them from time to time, but there is no noteworthy change at the surface of the earth until suddenly something seems to give way above, and a deluge of rain descends. These sudden downpours occur in dry regions, and though the cloud often bursts in the free air, it is more likely to do so if it drifts against a mountain.

Thunderstorms differ in being stationary or progressive, and there are all stages between those which do not move at all and those which travel eastward at the rate of twenty or thirty miles an hour. There is one common form which, as it moves forward, spreads out like a fan, and as it does so divides up into many thunderstorms. The map of such a rank of storms is like the diagram. The point of beginning is about *C*. As it starts eastward it spreads out along a curved line which divides up into several storms. More and more active centers with electric phenomena develop as it goes on eastward. For successive hours these are found along the curved lines marked 1, 2, 3, and so on. Finally, after a few hours

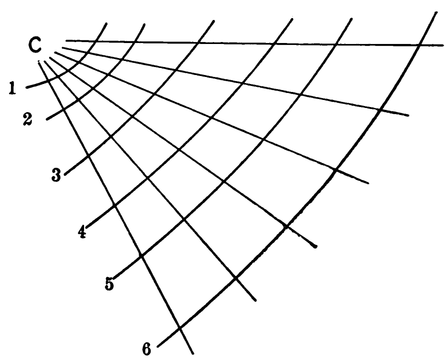


FIG. 41.—Ranks of thunderstorms gradually deploying.

they weaken and disappear. This form of ranked thunderstorms has been called a *derecho*.

The nature of the motion in thunderstorms is probably various. Some are certainly ascending whirls. A few have been found to be small descending currents of air. In many cases they occur, apparently, along a small wave of pressure in the air. This wave usually has its hollow at about the moment the thunderstorm breaks, and its crest just after. Probably in the *derecho* the curved lines 1, 2, 3 mark the successive positions of this crest. The change in pressure is small, and requires close observation to detect. Just in front of such a crest must be a considerable up-and-down change in the air. It may be like the critical axis of a cyclone, and the phenomenon may consist of small, temporary highs, lows, or horizontal walls.

Especial study of thunderstorms has been made in the last few years, for the reason that they are likely to do injury to agriculture and commerce, because of their sudden and unexpected appearance. They may catch a farmer in the midst of his haying and seriously injure his crop, or take a sailing vessel unawares and capsize it. The attempts at predicting their appearance at any given time or place have been barely successful, but the warnings less satisfactory. The storms are short-lived, and the people to be warned are at some distance from a telegraph or telephone station. The progress of the storms can sometimes be safely forecasted for several hours, but this is not time enough to reach and warn the persons whose interests are in danger.

CHAPTER XXIII.

LIGHTNING AND THUNDER.

THERE is as yet no good reason for thinking that electricity is one of the great causes of the weather and its changes. On the other hand, it is probably only an effect having very little to do with the weather, except to add to the beauty and terrors of its storms, especially when these are intense. It has one secondary effect which is interesting, and that is that after a sharp stroke of lightning the rain and hail fall more freely than before. It may be that electricity in some way is instrumental in holding up the drops of rain and the hailstones, or rather aids the other forces in holding them up, and that when it is discharged they fall; but no one yet understands how this action could be exerted. As an effect of storms—sometimes a very important one, and always one which strongly attracts the attention, and sometimes causes serious loss, and even death itself—the subject deserves discussion.

Now, the earth and the air are contrasted as to their electric condition. The air is positive and the earth negative. This produces an electric strain or tension between them. This strain they are always striving to neutralize by a discharge from one to the other.

Moreover, friction makes electricity or increases the strain between the positive and negative. By rubbing together the folds of the soft, light rubber cloth used by dentists this strain can be increased until long, sharp sparks can be drawn from it by pointing the finger at it, thus reducing the strain. The same thing can be done by scraping the feet along the carpet in a dry, well-heated room in winter. The person then becomes so charged with this strain that he can bring out a spark from himself by pointing his finger at some one else, or at a piece of metal. He can even light the gas by the spark when the conditions are very favorable. In some cases, too—as when the air is very dry and warm—the stroking of a cat brings out a series of sparks.

In the air there is constant rubbing or friction, and this tends to sharpen the strain. Thus the sand becomes charged when blown by a high wind over a desert, and it is doubtless in a similar way the clouds become highly charged. The result of all motions of the air is to make the stress stronger between air and earth, and to increase the tendency to relieve it by some kind of a discharge.

The discharge is likely to occur at all points reaching out from the earth. Thus, on a high, isolated mountain, the discharge can be found at almost any time. When the strain is high—as during a storm—the discharge may occur over a tree, and through it, or through a horse, or man, or house, or anything which is connected with the earth and stands up above it. The strain is particularly severe in snowstorms, in some of which the cloud seems to actually come down to the earth.

The discharges are gradual or abrupt. Among the gradual discharges is the one that is heard but not seen. It is experienced on mountain tops especially, and the one who is there can hear the crackling buzzing from his hair or his alpenstock. It often sounds like the buzzing of a bumblebee, and those who do not know about it try to find the bee and drive it away. They may be tormented by the idea that it is in some one's hat and fear that it will sting, but they hunt for it in vain.

Another slow discharge is visible, but

makes little or no noise. It appears like a little lambent flame on the head, on the vizor of the cap, on the shoulders, the cane, on the angles of stones—wherever there is a projecting point. There is no heat and no danger in the flame, and no danger generally in these slow, gentle exchanges of electricity between air and ground. Such lambent flames are occasionally seen in snowstorms even at the surface of the earth, but they are most common on mountain tops. The St. Elmo's fire that appears as flames on the masts of ships in some storms is an instance of this kind of electric discharge.

A very curious but rare form of discharge is what is called ball lightning. In this case a white ball, as if of cotton waste, descends quietly in the air and rolls along the ground. One once descended upon a load of lumber, rolled along the boards, dropped off at the end of the wagon, and disappeared; another came in the open door of the cabin of a French peasant, rolled across the floor, and disappeared up the chimney of the fireplace. Ball lightning is not often seen, and any explanation of its form or causes is yet unknown.

An abrupt discharge of electricity during a thunderstorm is the lightning; the tension between cloud and earth goes on increasing until it becomes strong enough to break its way through the air between. The discharge seems to be one, but photographs show that there are

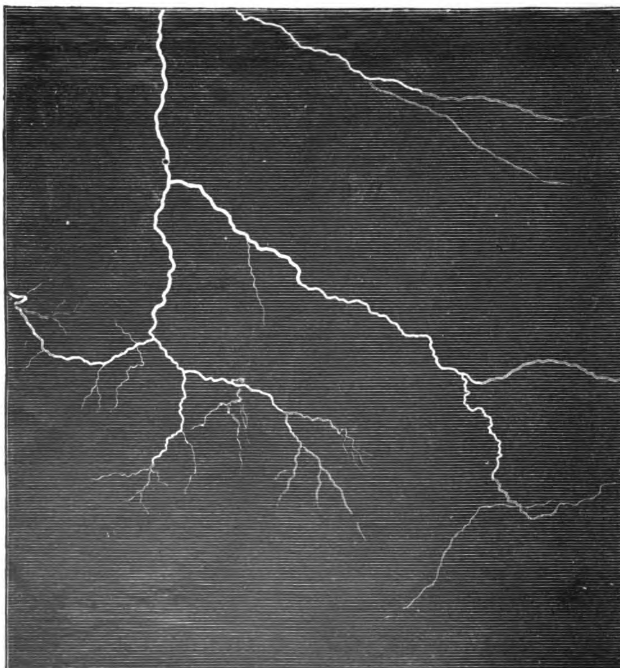


FIG. 42.—From a photograph.

many plays of the electric fluid back and forth between the air and earth, all in extremely rapid succession. The discharge is an electric spark like that drawn from an electric machine, which latter we can make only a few feet in length. Nature makes them thousands of feet long.

The discharge breaks and splits trees, or even resolves them into splinters like kindling wood, because it heats them intensely, and this suddenly makes high-pressure steam which explodes. It tears the boards from houses or sets them on fire for the same reason. Its fatal effects on life seem to be due not so much to the burning, and not at all to explosion, but to the shock. Hence it happens that persons made insensible by a stroke of lightning can often be brought to if immediately cared for.

Danger from lightning is almost nothing provided one keeps away from high places and from under trees during a thunderstorm, or has his house properly protected. Houses in cities are very rarely struck. They are so full of iron and other metal, and this is in such complete connection with the earth through the water and gas pipes that the tension above them is relieved by constant and silent exchange between the air and the earth. It is the house or barn that stands alone and without high trees around it that needs to be protected.

The principle in lightning conductors is that they must connect with the deeper moist earth through a good conductor of electricity those parts of the house most likely to be struck. Flat bands of copper are the best conductors. Metal points on the house tend to produce a silent and harmless discharge between air and earth. The most common causes of failure in lightning rods are carelessness and neglect. The rods are not large enough to conduct a heavy stroke, or they are not properly connected with the deeper damp soil, or they have been neglected and become broken or imperfect. A poor or imperfect rod is worse than none.

The broad, silent flashes of light between clouds are reflections on the clouds of lightning so distant that the thunder can not be heard. The thunder is the sound of the sudden coming together of the air, violently torn apart by the heat and energy of the lightning. This series of sounds is echoed and reflected from distant objects, thus giving the roll of the thunder. The sound of the thunder comes much more slowly than the light of the lightning. If one will count the number of seconds between the flash and the first hearing of the thunder and divide by five, it will give closely enough in miles the distance at which the flash took place.

CHAPTER XXIV.

THE WEATHER PROGRESS THROUGH THE DAY AND YEAR.

THE daily change in sunshine, alternating with darkness, causes a change in all the meteorological elements, and this is enough to control the occurrence of local storms, but not enough to have a marked effect on general storms or anticyclones. The change is therefore by far most appreciable in intermediate weather. It is most noteworthy in the winds when not controlled by great centers of pressure. In all cases not so controlled the movement of the sun causes a change in the direction of the wind, which varies with the character of the country around the station.

It is most interesting in the case of stations on the coast, where it gives rise to land and sea breezes. In the daytime the land becomes heated until it is warmer than the water. The heavier air of the ocean then presses in on the lighter air over the land, the latter rises, and the former flows in, producing the sea breeze. This begins along in the day, reaches its greatest strength late in the afternoon, and dies out early in the night. The sea then becomes warmer than the land, and the opposite process takes place, making the land breeze. These occur only when the land is free from snow and is not so chilled by the cold of winter that the temperature of the soil may not be notably increased by the rays of the sun.

The land and sea breezes belong to the warmer parts of the earth and to the warmer season of the year. They occur on the American coast to New England at least on the north, over the coast of the Gulf of Mexico, where they often extend far inland, and over the Pacific coast to Washington in clear weather. They also occur to a less degree and less regularly about such large bodies of water as the Great Lakes.

A similar daily change takes place among mountains when the air passes up the valley during the hot part of the day, and down during the colder part of the night.

The meteorological equator, or equator for the weather, is called the heat equator. It is near where the sun is vertical at noon and hence changes with the year, being so high north in midsummer as to pass just south of the peninsula of Florida, and so far south in midwinter as to cross the continent of South America on the parallel of Rio Janeiro. The ring of stormy weather over the temperate zone moves back and forth with the motions of the heat equator. It has fairly passed to the north of the United States, except Alaska, in the hottest part of the year, so that there we have very few general storms in that season. In the coldest season it passes to the farthest south, and reaches about to the coast of the Gulf of Mexico. The result is that in the southern tier of States there are few general storms except in winter, while in the Northern States general storms cross the country from autumn to spring.

Just south of this band of general storms is the region of local storms. This, like the other, also moves back and forth through the year, with the result that in the southern tier of States there are local storms in the spring, summer, and autumn, while in the northern tier they occur only in the hot season. In both cases the States lying between the northern and southern tiers have an intermediate condition as to the times of general and local storms.

Tornadoes take a somewhat different course through the year, because the American autumn is too dry to sustain them. They are likely to begin their season's work in the Gulf States in February and March, and to come gradually northward. They appear in the Middle States in April, May, and June, and in the higher Mississippi Valley and the States about the Great Lakes in summer. They are not common in the autumn and very infrequent in December and January.

There are certain well-marked rainy seasons in the United States. In the winter the Pacific coast has a definite season of rain, beginning in the late autumn and ending in the early spring. Local storms during the rest of the year are rare there, and lightning is very uncommon. In the spring and early summer there is a moderate rainy season east of the Rocky Mountains from Colorado northward into Canada and northeastward to Lake Superior. It generally ends in June. In Arizona and New Mexico there is a rainy season in late summer, due almost entirely to local storms. In the autumn a rainy season comes on in Florida, especially on the Atlantic coast. Its influence extends northward well up toward Cape Hatteras and westward for a short distance on the Gulf coast. The rest of the United States is driest in the late summer and the autumn.

In some parts of the world there is, according to the season, a change of wind of a character like that of the daily exchange of land and sea breezes already described. In the summer the land area, especially the dry interior, gets so heated that the air tends to rise and the sea air to pour in to take its place. In the winter the opposite is the case. This is called a monsoon, and is very appreciable in summer in favorable weather over the Mississippi Valley, generally to the west of that river. The Gulf wind then passes generally over Texas, and under favorable circumstances occasionally reaches the Canadian border.

There are a few special periods of weather through the year which are of great interest. Beginning with January, the coldest days of the year are likely to occur for two or three weeks from the middle of that month. The average coldest day of the year is about January 25th, or about a month after the winter solstice, when the sun is farthest south. This delay of a month is due to the slowness with which the earth and air lose their heat.

February 2d is a day that has, and has had for ages, a curious degree of popular interest without any justification in fact that has been shown by American weather. It is an excellent illustration of how pleasing notions, once formed, will persist without reason for many hundreds of years. This day is Candlemas Day, called in the United States Groundhog or Woodchuck Day. Of this day the old country people in Scotland say:

> "If Candlemas is fair and clear,
> There'll be two winters in the year."

In America the tradition is that on this day the woodchuck comes out of his winter resting place, and if he sees his shadow he returns for six weeks. Nearly all the European peoples have somewhat similar associations with the day. The weather idea underlying is that if clear weather has come on by the 2d of February a new period of winter will set in and spring will be late. There is no reason, so far as weather statistics show us, for this conclusion.

About the middle of May frosts are likely to recur both in Europe and in America. In central Europe the recurrence is supposed to take place on the 11th, 12th, and 13th of May, and the saints for these days are called the ice saints, because they bring ice out of season, and vine stealers, because the frosts of this date are likely to injure the vines. In the States there is also—at least in the North—some probability of frost in the latter part of June.

The hottest day in the year falls generally after the middle of July, about a month after the summer solstice. The sun is highest at the latter date, and the delay of a month is due to the slowness with which the earth and air heat up.

In the latter part of October or early in November there are often several days of warmer weather, corresponding in untimeliness to the May frosts. They are called Indian summer in the States, but St. Martin's summer in Canada, after the saint of November 11th. These days in the States are usually characterized by a blue haze or smoke in the air, which makes them very attractive, and they are generally calm. The smoke is sometimes attributed to the burning off of the trash of clearings, which is likely to be done about that time, because the dry weather preceding has made it ready and the winter's approach makes further delay undesirable.

CHAPTER XXV.

LOCAL INFLUENCES ON WEATHER.

LOCAL features, such as mountains, forests, lakes, have a noteworthy effect on the weather, so great as appreciably to add to or subtract from the prosperity and comfort of those who live near them. The coast weather is always less variable than the weather in the interior of a continent. Continental weather has sudden and severe changes of temperature, which are very trying to those who endure them, but which tend to make the strong stronger. This is the case to an especial degree in the middle of the continent of North America, because no lofty mountains shut off from it the cold air which at times sweeps down from the polar regions. The same is true of the most of Siberia; but Mongolia is protected from the north by mountains, as is also the valley of the Amur. These regions are in the latitude of the northern United States, and their climate, when of the same degree of dryness, is somewhat superior to that of the interior of the States. The climate of the western plains, even as far south as Texas, is subject to these severe changes of temperature.

On the other hand, the coast is subject to a greater amount of cloud and fog, and to a moisture—which though comfortable in moderate weather is very uncomfortable when the temperature is extreme; close and weakening when it is very hot; raw and searching when it is very cold. So the balance is pretty well preserved in the United States between the interior and the coast.

Fog is generally confined to the coast and to the mountains. It is most abundant and continuous on the coast of the extreme Northwest, where it may occur for many days in succession, and it sometimes lasts all day. It is next most common on the northern Atlantic coast. It is frequent on the Great Lakes in summer, and especially on Lake Superior. Fog makes depressing weather, not lessened by the dismal, oft-repeated moans of the warning fog horns near the harbors.

One of the features of what may be called artificial weather is the frequency of fogs near and over great cities on the coast. The fog grows more frequent and denser and continues longer in proportion as the city increases in size.

This is due to the dust and smoke produced, for these are fog-compellers, as already explained. The fogs in London in winter are so dense as to practically interrupt traffic while they continue. They are not so bad in New York, but are already at times a serious hindrance to commerce.

An effective weather control is a range of high mountains, especially when it crosses the usual direction of the wind. This is the case in the United States with the Rocky Mountains and the ranges along the Pacific coast. The effect is less in regions subject to frequent general storms, as in the extreme Northwest, but even here it is generally appreciable.

For instance, in the State of Washington the Cascade range is not very high. The western slope is covered with a dense growth of magnificent trees, the finest forest of large trees in the United States and one of the finest in the world. The forest is so dense that it is difficult to force one's way through it. A few miles on the railway, and a passage perhaps through a short tunnel, brings one out on the eastern slope of these mountains, and he seems to have passed into another world. There are but a few scattering, small trees on the mountain side, which are of other species than those of the more densely wooded slopes. Away off to the east are plains on which not a single tree is to be seen, except where it has been planted by settlers, or maintains a precarious existence in some cañon, above whose top it hardly dares to peep. The rainfall on the western slope is forty to sixty inches; on the eastern side it is only a quarter as much. On the western side the trees protect each other from the wind, but on the eastern the light rainfall does not permit them to gain sufficient vitality for this.

The wind, carrying a load of moisture from the warm Pacific, strikes on the western slopes of the mountains and is forced upward until it is chilled. It is then unable to sustain its load of moisture, and deposits it abundantly in the form of rain or snow on the western side. As it comes down on the eastern side it warms again, and, having lost its abundant humidity, is dry. The little rain that falls here is due to the general storms, that bring in some air from the north which has not crossed the mountains. Farther south, where general storms are less common, as in Nevada, the dryness on the eastern slope is extreme.

As the storm passes east in the higher latitudes it succeeds in storing up some more moisture, and this it deposits, though rather scantily, on the next range of mountains, the Bitterroot and Cœur d'Alène; and here is another, but less abundant, timber growth, and each high elevation between the two has a few trees. It strikes the mountains again in the vicinity of Helena, where another and thinner forest growth exists, and it finally comes out on the plains fairly devoid of moisture. Thus the western slope of these mountains is always more moist than the eastern, the plains to the east of the mountains are dry, and this dryness is greater the farther south we go.

Such is not the case with the Appalachian, Adirondack, and White, and Green Mountains, partly because they are constantly crossed by general storms, partly because they are low, and partly because the moist weather from the Atlantic reaches them.

Another effect of mountains, in this case true of less pretentious elevations, is that section called the warm zone, because warmer in winter than the bands higher up or lower down. This is especially noticeable on the Appalachians, and is due to air drainage.

Cold air is, as has often been said, heavier than warm air, consequently, it flows down inclines like water and seeks the lowest levels.

In cold, quiet weather it chills the lower places and leaves the warmer air above. This effect extends up to a limit, where it is balanced by the increased bareness and exposure which permits a greater loss of heat to the sky. Hence between this higher, more exposed zone and the lower level filled with cold air lies a band of milder temperatures.

This band is favorable to the farmer, and he can take advantage of the air drainage in other ways. For instance, in southern Michigan the climate is almost too cold for the finer kinds of peaches. In hollows and on level hilltops the trees are almost invariably injured by winter cold. If, however, the orchardist will plant them on a slope, so that the cold air may drain off, he will be able to raise peaches successfully.

Another and very remarkable effect of mountains is seen in the Chinook winds, which interrupt the cold of winter with an almost spring-like mildness on the plains east of the mountains from Colorado to the Peace River in Athabasca. The Chinooks are westerly winds which bring mild temperatures, and are so dry that they evaporate the snow without melting it. These are the winds which descend the mountains and become warm by forcing their way down into denser air. They have been made dry by the series of mountain ranges they have crossed. They render the climate of the northern plains much more inhabitable than they would otherwise be, and in the United States their influence reaches eastward to Minnesota.

A still more noteworthy wind of this sort occurs in the Alps, where it is called the *foehn.* Here the dryness is so great that the danger of fire in the Alpine villages is increased to such an extent that a special fire watch has to be set during the continuance of a *foehn.*

The weather of a dry region is like that under a high, as already described, and that of a wet region is like that under a low. They need hardly be further described, but there is one comparison between the two which throws much light on their relative comfort. It shows why the high temperatures of a dry climate may, with proper dress and ventilation, be made not only endurable but comfortable. Dry weather promotes evaporation from the surface of the skin. This produces cooling, and the greater the evaporation the greater is the reduction of temperature; the greater the heat and the drier the air, the more will the cooling be. On the other hand, the moister the air the less the evaporation and the less the cooling. The temperature of the skin under these circumstances, or rather the temperature of evaporation which the skin feels, has been called the sensible temperature. This will be the lower in proportion to the dryness of the air. If the air is very dry and hot, the reduction may be twenty degrees or more. When this happens the temperature of 110° in the shade, not rarely experienced in Arizona and New Mexico, may feel really cooler than the temperature of 95° at New York.

Forests affect climate and the weather materially. Within the forest are all the effects of shade and calm, as well as the saving of moisture. Outside there are also effects, though they are not such great ones. The forest serves as a wind-break for everything in its lee, and if the open areas are not very large they may be as well protected from the wind as if in the forest itself. Forests also reduce, by the roughness of their surface, the speed of winds that pass over them, thus checking the violence of the cyclone of which these winds are a part. They have some effect on local storms by controlling the heat of the surface air. The differences in these regards between a forest and an open plain are well recognized. Whether the forests also affect the amount of the rainfall, as is believed by many, is not so certain. It has not yet been proved beyond the possibility of a doubt. That they affect the way the rain falls, however, can not be doubted. In countries covered with forests the storms of very heavy rainfall called cloud-bursts, and similar storms, are nearly unknown.

CHAPTER XXVI.

WEATHER PREDICTIONS AS A REMEDY AGAINST WEATHER INJURIES.

THE earliest way men had of predicting the weather was by what is called the weather signs; and these, though sometimes spurious and often transported to climates where they are not applicable, may be good and genuine, and, to one who can not see the daily papers or who loves to study Nature in some of her most attractive moods, they may be of use and interest. One of the best known series of predictions is that of Dr. Jenner, the genial and accomplished discoverer of the efficiency of vaccination. He described them in verses that were published about a century ago. They are given here entire, as, with the exception of the rooks, they give a series of signs useful in the cooler and moister parts of the United States.

THE SIGNS OF RAIN.

The hollow winds begin to blow,
The clouds look black, the glass is low;

The soot falls down, the spaniels sleep,
And spiders from their cobwebs peep.
Last night the sun went pale to bed,
The moon in halos hid her head;
The boding shepherd heaves a sigh,
For see! a rainbow spans the sky.
The walls are damp, the ditches smell,
Closed is the pink-eyed pimpernel.
Hark how the chairs and tables crack!
Old Betty's joints are on the rack.
Loud quack the ducks, the peacocks cry,
The distant hills are looking nigh.
How restless are the snorting swine!
The busy flies disturb the kine;
Low o'er the grass the swallow wings,
The cricket, too, how sharp he sings!
Puss on the hearth, with velvet paws,
Sits wiping o'er her whiskered jaws;
Through the clear stream the fishes rise
And nimbly catch the incautious flies;
The glowworms, numerous and bright,
Illumed the dewy dell last night;
At dusk the squalid toad was seen
Hopping and crawling o'er the green;
The whirling dust the wind obeys,
And in the rapid eddy plays;
The frog has changed his yellow vest,
And in a russet coat is dressed;
Though June, the air is cold and still,
The mellow blackbird's voice is shrill;
My dog, so altered in his taste,
Quits mutton-bones on grass to feast;
And see yon rooks, how odd their flight!
They imitate the gliding kite,

And seem precipitate to fall,
As if they felt the piercing ball—
'Twill surely rain—I see with sorrow
Our jaunt must be put off to-morrow.

These are all familiar and interesting reactions to the increasing humidity in the atmosphere, and those relating to things without life can be easily explained. Some slight adaptations must be made for other climates, and it would be interesting for the reader to make them for his own locality. The only serious change for the Northeastern States is the cutting out of the four lines about the rooks, as we have no bird here which behaves in that way. Four additional lines might be devoted to the uneasiness and distress of our swallows at the approach of rain.

The sign which depends on the glass, or barometer, is, of course, generally true, and is the mainstay of the predictions of sailors, but people whose pursuits keep them much of the time in the open air, especially if they are affected by the weather, gradually acquire a sort of unconscious knowledge of coming weather for a day or more ahead which is quite trustworthy. The signs they use appear to be rather the signs of the sky than of the earth, and are to be found in the appearances and changes of clouds. Any one who watches the clouds attentively will see in them a great many trustworthy indications of coming weather. Those who live near mountains will find the study especially interesting.

Another and less satisfactory attempt at weather prediction is that which is based on the moon. This is really astrology, though notwithstanding its recent revival as a fad, astrology proper has long been thought dead. Astrological principles lie at the foundation of the predictions of the popular weather prophets as published in almanacs. Of these there are several which have quite a following for reasons that are not easy to understand. Such predictions are really of no use, for they are not right often enough to permit one to lay plans by them. We are unable to prove that any heavenly body except the sun, its prime mover, has an appreciable effect on the weather. The moon has no influence worth taking into account.

It is the methods of modern science which have enabled us to predict the weather with an accuracy great enough to be of some use. The two fundamental principles of modern science are that of the whirl or cyclone and anticyclone, and that of the easterly drift of the weather in the temperate zones.

Predictions are based on the weather map, a specimen of which is given on page 208. Isotherms, dotted (broken) lines, are drawn for each ten degrees. The isobars are solid lines, drawn for each tenth of an inch. Shaded areas indicate regions of precipitation during the preceding twenty-four hours. The arrows fly with the wind, and the circles have the following meaning:

⊙ Clear. ◑ Partly cloudy. ● Cloudy. Ⓡ Rain. Ⓢ Snow.

Now, the cyclones are for that date and hour at the words LOW, and the anticyclones at the words HIGH. The prediction consists in foreseeing how far these centers will advance in the next thirty-six hours, what direction they will take, and how much change may be undergone by them and by the intermediate weather. In general, the weather will shift forward on the map about seven hundred and fifty miles in that time.

If the reader will imagine the centers of pressure to have advanced this distance and to carry their weather with them, he will have made a genuine prediction, though perhaps not an accurate one. Experienced forecasters are

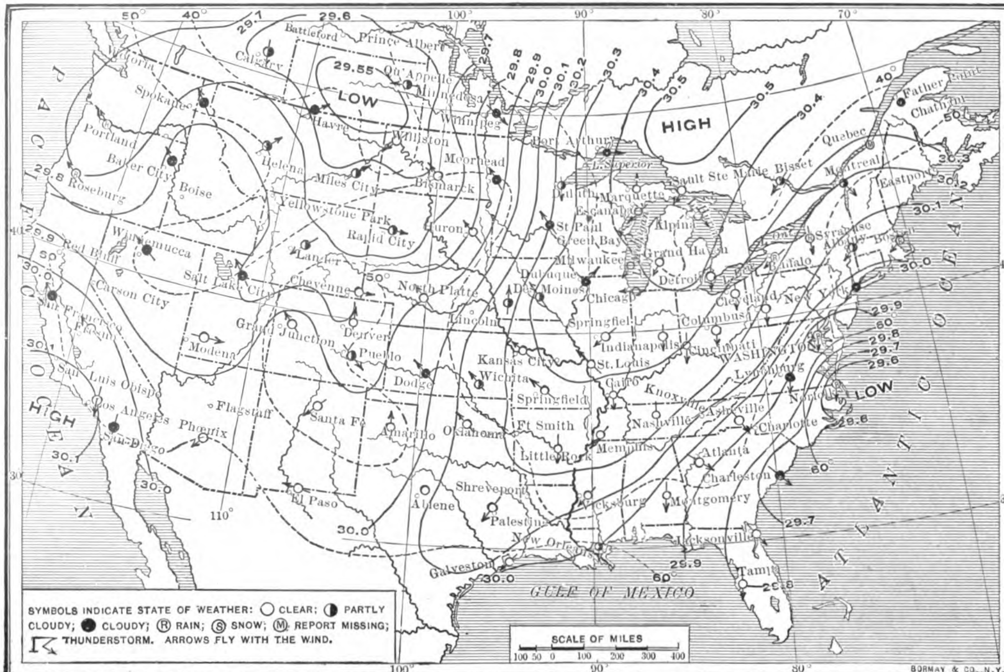


FIG. 43.—U. S. weather map, published Saturday, Oct. 10, 1903, by the Chicago station. Forecast for Chicago: fair to-night and probably Sunday; warmer Sunday; winds shifting to southerly and increasing.

entitled to a grade of ninety per cent on the accuracy of their predictions.

The work of observation, collection, tabulation, and map-making is done by a weather service. In the United States this employs several hundred men, and costs over a million dollars a year. There are perhaps a score of other weather services covering the civilized countries generally in the world, but the American is the largest and on the whole makes the best forecasts. It is also by far the most expensive; this is due both to the area it covers and to the perfection of its work.

The chief difficulty of the weather service, after all, is to be sure that its warnings will reach those most interested—the farmer and the transportation managers. The warnings are published in the daily papers, but are only for the day ahead, and so do not continue long of value. The readers of the daily papers are very numerous, but the list does not include most farmers nor many engaged in marine commerce. Those engaged in land commerce can be easily reached in several ways, the others only with difficulty in the short time during which the prediction runs. Various ingenious devices have been invented, and some tried; but no satisfactory means have yet been found of reaching, in time, the farmer more than two miles from a town on the railway, or a seaman not near port. The first part of the problem is being solved by the extension of the telephone and the free delivery of mail over the rural districts, the latter service having experienced a marvelous development in the last few years. With wireless telegraphy and other improved means it may be that satisfactory communication can soon be extended at sea.

The prediction of the weather, though abundantly accurate, solves only in part the problem of weather protection. The warnings must reach the sufferer in time to save him. Even then the protection is not complete, for the recipient must know how to protect himself when forewarned. Because he knows a flood is due the next day, it does not follow that he can move his house out of harm's way. Probably man will never be able to evade or escape the weather completely. But what he can do will depend on his knowledge, and the knowledge he will most need for this purpose is that of the weather itself. The history, present state, and prospects of the science of the weather we will sketch briefly in the next chapter.

CHAPTER XXVII.

THE PROGRESS OF KNOWLEDGE OF THE WEATHER.

THERE is perhaps nothing which has been more talked about to less purpose than the weather. The first real step toward any scientific knowledge of the weather was in the invention of the barometer nearly three centuries ago. Accurate observations with it soon began, and observations on the temperature, wind, and rain rapidly followed, but the key to the series was not discovered, and the observations were collected in myriads all over the earth to almost very little purpose. This is true so far as weather was concerned; as to climate, these observations had given much information, and this is condensed and shown in the better maps of the climate of the earth.

It was not until the happy idea of taking simultaneous observations at places far apart had been put into practice that further light was thrown on the problems of the weather.

This was done first—in the States at least—by Thomas Jefferson, who afterward became President of the United States. He was an accomplished and many-sided man, and was always interested in meteorology. When at the Constitutional Convention in Philadelphia he provided himself with a thermometer, with which he took observations wherever he went, recording them in his private papers. While living at Monticello, near the University of Virginia, which he founded, and which still remains a unique and useful institution, he prevailed on Bishop Madison, who lived near Norfolk, across the great State of Virginia, to take with him simultaneous observations with the barometer.

This did not continue long, and the next real step in advance occurred a generation later by those who undertook to study the destructive hurricanes of the West Indies. They made as perfect weather maps as they could, and soon discovered both the great facts that the storms are whirls, and that they move eastward. A great controversy raged about these discoveries, and they were in time verified, but nothing could be done in weather prediction until the telegraph was invented and used. This came some years later, and Morse was occupied for years in getting it into use. The interest in the weather controversy was so great that the telegraph was expected to be chiefly useful in enabling the weather to be predicted. Few seem to have anticipated its enormous value in general commerce and in the collection of news.

After the telegraph had been extended to distant parts of the country, it was employed by Professor Henry to get material for a daily weather map which he had prepared and posted in the Capitol at Washington. The civil war soon interrupted this work, and it was not resumed until 1870, when Professor Abbe began it with the aid of the Western Union Telegraph Company, with center at Cincinnati. Between Professor Henry's attempt and that of Professor Abbe, weather prediction had been undertaken by several foreign governments. By the latter part of 1870 it was engaged in the United States Government under the direction of General Myer, of the army. Since then weather-map making has spread over the civilized world and developed slowly in usefulness. The chief advance has been in the development of the instruments which are now very perfect, and register results continuously and automatically, so that the weather for any moment can be ascertained. The only element not thus registered is the moisture of the air, and this is still imperfectly observed, though it is of great importance.

There are three lines in which advance has been attempted and is still going on. The first is that of the weather of the polar regions. A better knowledge of this is necessary, because the atmosphere is one great machine, and what happens in one part of it is dependent to some degree on what happens elsewhere. Great expenditure of money and of human effort and life has been made to perfect our knowledge of polar weather. One of the most notable of these attempts was the daring but disastrous one conducted by General Greely to Lady Franklin Bay in the high north. With our present experience, life in an arctic winter has become safer, and we have reason to hope that the necessary knowledge of this sort will soon be provided.

The next field of weather exploration to be undertaken was that of the upper air. We are down to the bottom of the aërial ocean, where it is not easy to take observations of any considerable elevations except the clouds. There has been an attempt to fill this vacancy of knowledge by observatories on high mountains. These have now all been abandoned in the United States to the great regret of students of the weather all over the world, but such observatories are maintained in many foreign countries. The work is also done by balloons, and regular balloon weather observations have been extensively carried on. In the United States Prof. Henry A. Hazen is the most persistent and daring of observers from balloons. Investigations of the weather are also supplemented by observations with registering instruments carried up by kites, and, as the art of kite-flying improves, these prove more and more useful. Systematic observations with balloons and kites will soon give us a great deal of light on the phenomena of the weather.

There are two planes of activity in natural weather-making—the surface of the earth and the cloud layer. For ordinary weather the earth's surface is probably the more active; but the origin of the intense, and therefore most important and most destructive, storms seems to be above.

The third line of advance in weather lore is in the prediction of the weather for seasons. This has been attempted in many ways, and there appear to be two in which there has been a slight degree of success. The one depends on the activity of the sun, as shown chiefly in the presence or absence of sun spots. There is undoubtedly a general difference in the weather for different parts of the sun-spot cycle, but this difference varies in different parts of the earth's surface. Such predictions promise little beyond general results, such as good harvests or bad ones, much rain or little, more local storms or less, and so on.

Rather more hopeful is the prediction of the seasons in regions where regular monsoons occur, as in India. In such places the conditions during one monsoon, and especially the amount of snow on the mountains in winter, are believed to be a fair indication of the next season. Some success is claimed in India for such predictions.

A number of interesting experiments, beginning as far back as February 4, 1891, have been and are being made in weather prophecy by the aid of gas balloons, and of fire balloons, and, as has been noted, of kites; these experiments promise valuable results.

In the use of kites, Mr. William A. Eddy, the experimenter, writes:

"The principal obstacles which remain to be overcome are dead calms and the sudden rush of thunder showers.

"The conditions of thunderstorm prophecy are peculiar in that while these storms may be extremely local, they at the same time form themselves into a more or less unbroken line of five hundred or one thousand miles in length, advancing rapidly, but in the form of a vast line of battle. This line of local storms is at times broken by irregular motions, and by storms that seem to go around certain regions. There is no doubt that electrical observations with my kite-sustained copper wire will determine whether a thunderstorm is approaching, receding, or simply circling around at an equal distance from the center of observation.

"A copper wire fastened to a rectangular frame coated with tinfoil is raised into the air suspended from the kite string. Electric sparks are then drawn to an iron spike, driven into the ground, and the length of the spark gap is measured. The presence of thunderstorm conditions is indicated by the fact that sparks begin before the tinfoil collector has reached a height of much more than one hundred feet. The thunderstorm may be miles away or far beyond the horizon, yet its influence, like that of a coil spark in wireless telegraphy, is revealed by the abnormal frequency and brilliance of the sparks drawn from my electric wire reaching from a high point on the kite string down into the earth through the iron spike, which draws the spark.

"During the great kite ascensions at Blue Hill Observatory, near Boston, where about five miles of steel wire was paid out upward, sustained by kites, reaching the greatest kite altitudes ever attained, it was found that some clouds are invisible, but are revealed by the humidity apparatus passing through them. Since 1892, during hundreds of observations, I had noticed that the approach of clouds overhead when the kite-sustained copper wire was aloft invariably caused an increase in the length of sparks drawn from the kite wire, while the recession of the cloud caused a marked diminution in the spark length. During an evenly clouded sky the sparks were steady, while during a clear sky the sparks were smaller, but also steady. The sparks increase in length with increased height under all circumstances, but they vary greatly with cloudiness. The relation of kite electricity to local storms was shown during a passing squall, when the electric sparks crackled from the kite wire to the iron spike in an almost incessant stream. But as soon as the air began to clear not a spark could be drawn until I had sent the collector to twice its previous altitude, and even then the sparks were faint. Had I tripled the height of the collector, the sparks would have come again as before, but the experiment showed that probably more than two thirds of the electricity had been dissipated by the passing storm, while in advance of the storm the electricity was in full force. The extent of the electrical excitement of the kite wire is in proportion to the intensity of the storm, and as the storm passes away instead of lessening two thirds of the electricity there may be a decrease of seven eighths.

"When a thunderstorm approaches within twenty miles of the kites I may get more electric force with my electric collector at a height of one hundred feet than I would obtain after the storm had passed with my electric collector at a height of eight hundred feet. I have not yet left my kite electric apparatus aloft during a passing thunderstorm. The lightning would be almost certain to strike so good a conductor as a kite-sustained copper wire, and the rush of wind in advance of such a storm would destroy the strongest kite ever made, or break the kite cable.

"Marconi has shown us that sparks radiate force to great distances, depending on the height from which the sparks emanate. The electric force of the coil-spark in wireless telegraphy is of a lower tension and different wave-length from that in atmospheric electricity, yet it is obvious that the lightning flash may cause effects at vastly greater distances than any covered by the tamer electricity manufactured artificially, unless we consider the wonderful high-tension electric forces handled by Tesla. The forecasts of the approach of thunderstorms which are hundreds of miles away are indicated at Bayonne by the flashing of the kite wire, and part of the work which I am carrying on is to attempt to locate the exact distance of the thunderstorm within a few miles, as the ocean cable experts now locate the exact point in the break in an ocean cable.

"The hot-air or gas balloon, operated in cooperation with Professor Langley, of the Smithsonian Institution, is also a valuable weather prophet at times when kites can not be flown, owing to dead calms, and when there is no time to inflate and send aloft a ponderous balloon with a man suspended below it. I am as yet almost without data obtained during a dead calm. On April 25, 1899, I sent up my first hot-air balloon in a light wind, with a self-recording thermometer suspended about twelve feet below it, at 8:15 p. m. The earth temperature was 69°, while the temperature aloft was 66°, a fall of 3°. The hot air in the balloon seemed to have no effect on the thermometer, because the hot air and smoke ascended twelve feet ahead of the thermometer, and when the balloon began to fall the hot air issuing from it still ascended.

"Electric wire tests will also soon be made with this balloon as well as tests of wireless telegraphy.

"The most marked advance which I have recently made in kite electricity is to send aloft a Leyden jar, suspended from the kite cable. Electric sparks were drawn from the jar when it was within sixty feet of the earth, and powerful brush lights formed with a hissing sound when the terminals were four inches apart. This will enable me to measure the distance of a thunderstorm with much greater accuracy and without the use of very expensive and delicate instruments. The thermometrical tests of the upper air are still actively under way at Blue Hill Observatory, at Bayonne, and, so far as known, at Washington, D. C., and at the sixteen kite observation stations established by the Weather Bureau in the central West. The European meteorological observatories are rapidly being equipped with kites, as pointed out by A. L. Rotch, director and founder of Blue Hill Observatory. Reports of the kite observations in Europe and by the Weather Bureau are still pending, and thousands of kite observations in all parts of the world will doubtless soon be classified, when I hope to have the honor of presenting still later facts. Meantime, my experiments at Bayonne will continue along new and difficult lines of investigation."

CHAPTER XXVIII.

EXPERIMENTING WITH THE AIR.

THERE is great pleasure and much information to be gained by experimenting for one's self in any of the sciences. It is much better than studying books, though the latter is necessary to show one what to look for and how to look for it. Such experiments make what is called the laboratory method in teaching, and they teach the student very thoroughly and tell him many things that the books fail to teach. Learning through the eye and the hand is more thorough and more attractive than learning from books. The atmosphere offers very many ways of learning in this manner, and what it teaches us is of great use in everyday life; it teaches one to understand, and watch, and take an intelligent interest in the great panorama of the weather which is constantly unrolling before us.

Studies of the atmosphere and its changes may be carried on in three different ways.

One is by making simple instruments and seeing what they will tell us; the other is by watching what goes on about us and by trying to explain it. The first is the way of experiments, the second that of general observation. A third way is to buy the excellent instruments used by meteorologists and to take regular observations with them. In this chapter we will describe some simple instruments which can be easily made, and experiments which can be conducted with them.

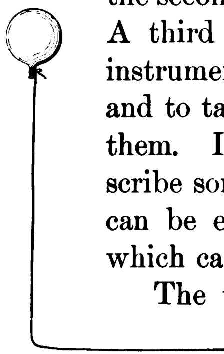


FIG. 44.—Toy balloon barometer.

The toy rubber balloon is a very fair barometer, and if it could be made so that it would not leak gas it would be an excellent one. If a cord or light long chain is attached to one of these balloons so as to keep it three or four feet from the floor, with a long string lying on the floor, then when the pressure rises the balloon will rise, and will sustain a greater length of twine; when it falls, the balloon will descend and the length of the cord will be shorter. The observation is made by measuring the length of the cord between the floor and balloon, or the height of the balloon from the floor. The balloon will lose gas more slowly if it is varnished.

Another arrangement for the pressure of the air was patented many years ago, and is very simple. It is a long pole, carefully balanced with a small heavy weight at one end and a much larger and lighter one at the other. The heavy weight may be a piece of lead, the lighter a closed tin box. This simple device plays up and down with changes in air pressure; the larger weight being up when the air pressure is high, and down when the pressure is low. The more probable the storm the lower the larger end will be. If this end is painted white and is large it can be seen at a distance.

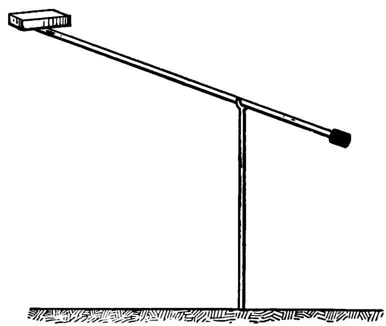


FIG. 45.

The experimenter can easily make a simple barometer at little expense. A glass tube, three feet long, with a bore about the size of a lead pencil with one end closed must be provided. This tube should be carefully cleaned and dried inside, filled with mercury and, with the finger on the open end, turned down, thrust into a small glass jar or bottle of mercury, and the finger removed. The mercury will descend six or eight inches, and the barometer is made. It must then be fastened securely, and a three-foot scale placed behind it, with the end even with the surface of mercury in the bowl. The top of the column of mercury rises and falls with the pressure.

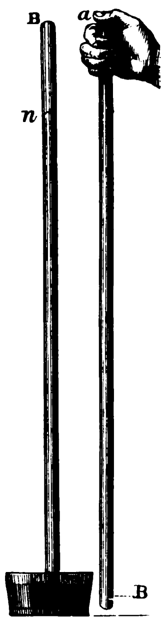


FIG. 46.—The mercurial barometer. The glass tube held on the right hand is closed at *B*. It is reversed in a basin of mercury on the left hand and the mercury in the tube falls to *n*, at which point it is sustained by the pressure of the air on the surface of the mercury in the basin. The space above *n* is a vacuum.

A similar barometer can be made of water, but it will have to have a tube thirty-six feet long above the surface. Besides, the water will evaporate and change the readings. So large a barometer would attract attention, and the changes in it would be measured by feet instead of inches.

Glycerin could be used instead of water, and this would not evaporate. The glycerin would be so much lighter than the mercury that the tube would have to be twenty-six feet long. It is expensive to make and to erect after the material is obtained. The expense could be lessened by having all the tubes of metal, except the last six or eight feet, which should be of glass. An inch of change in a mercurial barometer would here make nearly a foot. It could be erected on the stairway or in the vacant central space often found in large school and other buildings, and would make the changes in the pressure of the air very plain and easy to see.

An interesting thermometer can be made by fastening together two strips of materials differing greatly in their expansion when heated. Whalebone or hard rubber could form one of the strips and steel the other. If these are fastened firmly together, the combined strip will bend toward the steel when colder and away from it when warmer. The apparatus is sometimes used to regulate temperature in incubators and other places where this must be kept very even. They are so placed that they close the draft when the temperature is too high and open it when too low. A suitable one, large enough, could be put on the furnace of a dwelling. It may be made capable of raising a heavy draft door or valve.

A toy windmill may be used for measuring the speed of the wind if some way is added for counting the number of revolutions. This can be done by having a very small spool on the axis of the mill on which is wound up thread from a very large spool carrying a pointer. A much better way, but more difficult to make, would be a set of cogs with two pointers, one for single revolutions, the other for hundreds, and perhaps a third for thousands, like the counters on a gas meter. The number of revolutions for a mile of wind could be had by carrying the mill on a flat car on a railway train for a known distance. The mill must work very easily and smoothly to turn for gentle winds. It should be carried on a wind vane, in order to always be faced to the wind.

There are very many ways of roughly getting the signs of change in the moisture. One is by dry common salt, which absorbs it and becomes damp, increasing in weight as the moisture increases.

A better way is to use a long, smooth hair, for hair has great capacity for absorbing moisture. It increases in length when the air grows more moist, and shortens when it is dry. The human hair is excellent for this purpose. A long hair should be selected and carefully washed several times in weak ammonia to take out the oil. It should then be suspended at one end, passed several times around a spool, as in the diagram, and weighted at the other to keep it taut. The spool should turn very easily, and as the hair lengthens or shortens it will turn forward and back. If it carries a pointer and scale, the turns can be observed, and the grades will be from dry to wet. This is the hair hygrometer, and delicate ones can be bought which will serve very well the purpose intended.

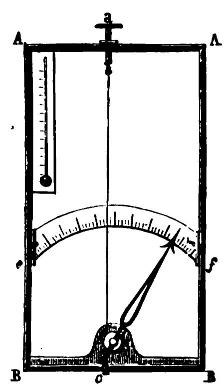


FIG. 47.—Hair hygrometer.

The toy which represents a dancing girl, the color of whose clothing changes from blue to pink as the air grows more moist, or back again as it grows drier, is an interesting weather predicter. It depends on certain chemicals which change color with their gain or loss of moisture. Among these is the chloride of cobalt.

Wedgewood, the celebrated pottery maker, constructed a toy of a different sort, which, however, depended on the moisture of the air for its action. It was a small wooden horse, with points on its feet directed backward. This, when left undisturbed, gradually made its way across a room. When the air was moist it lengthened, and the fore feet advanced; when the air was drier it shortened, and, the fore feet being held by the points, the hind feet were drawn up toward it. Thus with each change in the moisture of the air it made a step forward, and in time completed a passage across the room.

The heat can make so heavy an object as a rail of railway iron travel in the same way if there is a point fixed to each end, both set in the same direction. Each hot summer day makes it reach out a little forward, and the following cool night makes it contract: and the summer's progress is not inconsiderable.

The rapidity of evaporation is another means of testing the dryness of the air. This is not easy to test, for the evaporation varies with the weather, with the supply of water, and also with the character and colors of the material from which evaporation occurs—soil, surface, dead leaves, and so on. A very simple and useful evaporation instrument giving good results from day to day is that proposed by Piche. It is made by filling a test tube with water, placing a little circle of blotting paper on the top, reversing with a clamp on the paper, as in the picture. It is then to be fastened up by a wooden clamp, so that it will stand erect. The measurement consists in taking the height of the column of water, *a*, from time to time. The decrease is due to water evaporated from the wet surface, *b*, since the last observation. If two such arrangements, or evaporimeters, are used they must be as nearly alike as possible, so that they will give results that can be compared.

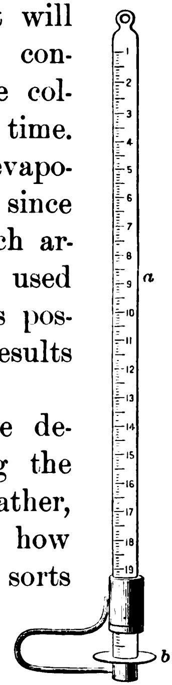


FIG. 48.—Piche's evaporimeter.

There are many other simple devices for showing and measuring the changes in the elements of the weather, but these are enough to show how they may be made and what sorts of experiments they will permit. An ingenious person will think of many others. Their value lies chiefly in making one familiar with the changes constantly going on in the air, though invisible except for their effects.

CHAPTER XXIX.

SIMPLE RESULTS OF WEATHER CHANGES.

The changes in the humidity of the air are fertile in producing changes in the familiar objects with which the reader is surrounded. Wood, especially when not varnished or oiled, absorbs moisture readily. The result is that the joints of furniture swell when the moisture is increasing, and chairs and tables creak and give out the loud reports often heard in a house. The catgut strings of musical instruments moisten and lengthen, and thus get out of tune. Doors and windows swell, and are hard to open or close. The down of the dandelion contracts. Fir cones hung up in the house where the air passes them freely, close their scales against wet weather and open again for dry, and the same thing happens for the prickles of the teasel. A piece of kelp or sea-weed absorbs moisture so readily that it becomes damp before rain. The strings of a spider's web become lax in moist weather, but tighten up when it dries. Gossamer and light seeds with plumes, like the thistle seeds, fly when the air is dry, but gradually subside as it becomes more moist. Absorptive salts and chemicals imbibe moisture, and some of them become so wet as to be half liquid. Thirsty plants also take in moisture, and in hot weather, when the plants are becoming lax and drooping from lack of sufficient water, the increasing moisture causes them to fill out and stiffen again without any visible reason for the change.

The sweating of walls and stones is a sign of the same sort. This is a real dew, and when abundant indicates also that the winter's cold still remains in the walls. In climates where changes in moisture are very great, special provision has to be made against the sweating of walls. Under such conditions even the great lens of a telescope may have so much moisture deposited on it as to interfere with the work of the astronomer. The increase of dew proper is also an indication of this increase of moisture, and this is one of Nature's ways to feed plants where the rain may be insufficient.

The change in quantity of moisture also changes the qualities of the air. The sun's rays are more easily trapped by moisture than by dry air, and consequently they do not seem so hot to us as in dry weather. In arid countries or at high elevations (as at Santa Fé or the city of Mexico, each about seven thousand feet above the sea) there is little moisture in the air, and the sun's rays are in summer so strong that passing from the shady to the sunny side of the street is almost like receiving a blow. At lower levels, especially in a moist climate, as in Florida, the distinction between shade and sunshine is not so marked. At the same time the air becomes more heated in the moist climate, so that the house does not furnish so much comfort and the moisture obstructs the evaporation from the surface of the body. When the sun's rays seem unusually hot and burning and the shade unusually cool, it is a sign that there is little moisture in the air.

Moisture also has an effect on the acoustics and transparency of the air. One can hear and see farther in quiet moist air than in dry. This is probably an indirect effect due to the settling of the motes of the air. These, although individually invisible, give the air a sort of turbidity which lessens both its capacity for conveying sound and its transparency, but the motes are capable, in many cases, of absorbing moisture, and, in all cases, of having it condense on them. This increases their weight and causes them to settle. A center of high pressure with settling air, if not too long continued, has the same effect by replacing the dusty air at the surface by the clearer air from above, rendered also denser by its motion downward.

Thus the downward motion in the high brings at first purer air in which sounds can be heard with remarkable distinctness, especially from hill to hill. Such a transparency to sound is rather a sign of settled weather than of change. If, however, a high remains long over one place, it promotes by its dryness and calmness the formation of dust, and thus in time increases the turbidity of the air.

The low improves the drafts of chimneys, because the air it brings is generally nearly calm, and the contrast in temperature between the heated air from the flue and the outer air enables the latter to rise. A low also improves the draft near its center, for then there is a marked tendency upward, but the horizontal currents tend to draw the column of smoke to one side. When, therefore, the column of smoke rises to some height straight in the air, it usually indicates the presence of a high with prospects of calm and sunny weather. In general, the presence of a high improves the symmetry of the column of smoke, but that of a low improves the draft.

The low also draws air from the earth, from mines, and from drains. In the mines the effect is to draw out inflammable gases, increase the amount of coal dust, and so make destructive explosions more probable. By drawing the air out of the soil it permits the soil waters to rise and increases the flow of springs and the height of water in wells. Indeed, some wells have been found to be good barometers. By drawing air out from the drains and sewers an approaching low heralds itself by the bad odors which it calls out.

As summer local storms, and even a great general storm, if intense, approach, all Nature is seized with a sort of unrest. The animals, perhaps most affected by the increasing moisture, perhaps by an instinctive knowledge of danger approaching, go through with a series of actions unusual to them. These are especially noticeable with our friends and near acquaintances, the domesticated animals—the dog, cat, horse, cow, hog, goat, fowls—each one of which has its own signs of unrest and anxiety. The bees hasten home and there show a state of great excitement, while the ants hurry the closing of the outer gates of their subterranean city. Even man feels some of the mental excitement, while his physical system reminds him of his gout or rheumatism or neuralgia, and the plants rustle their leaves as if they, too, had nervous tremors. The lightning flashes; the rain or hail rattles; the air, at first tremulous and sending up the leaves and dust in little whirls, then settling down to a good fresh blow, now becomes calm for a few moments. The rolling, heaving clouds pass by, the sun comes out suddenly and shines with renewed energy, and a gentle breeze springs up from a new quarter. The storm is over, all nature is again cheerful, and the animals return to their usual pursuits.

There is one sign of approaching wind which is usually neglected, and that is the twinkling of the stars. This, it has been proved of late years, is due to winds in the upper atmosphere which, by changing and breaking up the uniformity of the air, cause some such variations in the light as are seen in the air rising from a hot stove. Now, a high wind in the upper air is likely to descend, hence the twinkling is a sign not only of winds above, but of winds likely to appear soon at the surface of the earth.

The size of the crystals of snow is an indication of the temperature where they are formed. The larger the crystal the higher the temperature, and the lowest temperatures in which snow is formed are those where the crystals are minute sharp needles like those in a blizzard.

The best of all indicators of the weather, however, is the barometer. The pressure of the air is the simplest meteorological element and the one most indicative of ascending and descending currents of air; and these are, as we have seen, the necessary phenomena of storms—the more marked, the more intense the storm. For one who wishes to study the weather changes seriously, or whose comfort or interest depends on knowing them as long beforehand as possible, a good barometer is indispensable. If it is desired to make these changes visible in a schoolroom, the great glycerin barometer will give the best results. A series of mirrors could be easily arranged, which would bring down the head of the column and make it visible in a large hall by every one in the assembly.

Should any reader of this book wish to continue his studies of the weather, and to take regular observations, his best way is to write to the Section of the Crop and Weather

Service of his State, and join its staff of observers. He will then perhaps be provided with certain instruments, and with sheets for registration and full instructions for making his observations. He may also have the satisfaction of knowing that his observations will be useful to others than himself, and that the results will be published, and he will receive not only these publications, but others that will be useful to him. For a yet more advanced study a set of registering instruments will be needed, and these must be obtained from the dealers in such articles.

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