The rain from every cloud always comes down more or less intermittently, it may be in short, heavy showers, or in longer, gentle alternations. We do not know enough of the natural process by which rain is formed within a cloud to understand why this intermittent action should so generally occur, but any one watching the progress of a rain cloud from some height where he may command a broad landscape will observe it dropping its rain here and there as it moves along. Even if there were no connection, by way of cause and effect, between the noise of the thunder and the fall of the rain, yet there would always be some observers in the path of the rain cloud who would be able to say that the rain fell upon them just after they heard the thunder. There will, of course, be many more who will have observed that the rain came with or even before the thunder, and it will hardly do for us to attempt to explain the reasons why heavy rain follows the thunder until we have first satisfied ourselves that it does not equally often precede the thunder. It would take a very careful observer to accumulate the necessary statistics. He should give us the following numerical data, viz: How many times in the course of a year has heavy rain followed after the thunder within 1, 2, or .... 10 seconds and how many times has the rain preceded the thunder by 1, 2, or .... 10 seconds?

There can be no doubt but what thunder, which is formed simultaneously with the lightning, reaches the observer's ears some time after he sees the flash, and the Editor has always thought it likely that the special showers of rain have a direct connection with the flash rather than with the thunder. So far as his own observations go, the shower has always followed the flash and not the thunder; in fact, the thunder and shower often reach us at the same time. Some very accurate observations on thunder and lightning were recorded by Mr. Stillman Masterman, of Weld, Franklin County, Me., both at that place and at Stillwater, Minn. These are published in the Annual Report of the Smithsonian for 1855, pages 265–282. His records give the details of each individual flash of lightning and resulting thunder. In the storm of the afternoon of July 9, 1854, the details of over fifty flashes are given, and one case is noted in which a flash, whose thunder became audible within two seconds and was entirely over within five seconds, was preceded by the gush of rain. Similarly, in the storm of September 6, 1854, one flash was preceded by five seconds and another flash was preceded by one second, by the gush of rain. On June 14 and 15, 1852, Mr. Masterman says:

> I noticed that for several succeeding discharges of the electric fluid, there was in every instance a sudden and violent gush of rain, immediately *previous* to the flash of lightning. I have observed a like phenomenon on several previous occasions.

It is at present an open question whether the gushes of rain in any way bring about the formation of lightning, or whether the formation of lightning produces or accompanies the formation of the raindrops. In fact, both may be true, each under appropriate circumstances, but there is no reason to associate the thunder and the gushes of rain together as a case of cause and effect.

(1) When gushes of rain closely attend the lightning it is not improper to consider the falling rain as a mass of electrified drops conveying the electricity from the cloud region to the earth's surface; when they have approached the latter within "the striking distance," then the flash of lightning springs forth. The occurrence of the lightning is, therefore, in such cases due to the presence of a column of descending raindrops.

(2) When the rain precedes lightning by several seconds, as in the case observed by Mr. Masterman, this explanation, of course, does not apply.

(3) When the rain follows the lightning at an interval of several seconds the connection betwen them may be either accidental or casual.

(3*a*) In the first case, the rain started from the cloud independently of the lightning and reached the observer a few seconds later, partly because it took that time to reach the ground, and partly because it took time to be carried along horizontally by the wind as it fell to the earth. Both the vertical motion and the horizontal motion are involved in the time that elapses between leaving the cloud and reaching the observer.

(3*b*) If the connection is causal then, probably the lightning and the raindrops are formed at the same instant, and the time that elapses between the observer's observation of the flash and the shower is essentially the time occupied by the drops in falling to the earth's surface.

As the Editor has elsewhere said, a cloud is essentially a collection of particles of water condensed upon dust and other foreign matter as nuclei. These particles are surrounded by an atmosphere that is saturated with vapor but not yet condensed. As this saturated air cools it becomes supersaturated, and when this condition has proceeded to a point comparable with that which obtains in a state of unstable equilibrium, the vapor molecules from a comparatively large sphere of supersaturated space are, by their molecular attractions, suddenly brought together into heavy drops of warm water and descend rapidly from the clouds while the latent heat of condensation is communicated to the adjoining air and left behind in the cloud. At the same moment electricity, possibly due to the molecular disruption involved in the passage of vapor from the condition of extreme supersaturation to the sudden formation of large drops of water, or possibly of snow or ice, gives rise to the lightning flash.

All these suggestions looking toward an explanation of the connection between thunder, lightning, and gushes of rain must be understood to be merely so-called working hypotheses, which need to be tested by further experiment and corrected, and possibly entirely abandoned.

IMPORTANCE OF SOUND THEORIES.

It is very common to hear it said that "facts are more important than theories," by which we are to understand that untried theories or fanciful hypotheses are intended; the theories of a person who is not in touch with actual experience. Meteorologists, in their attempts to get at the laws of nature, have always suffered, from the fact that they can not experiment with the atmosphere on a large scale; we can even rarely collect enough observations to enable us to understand what is going on above and below over any large storm area. The history of our science has been, like the history of every other branch of science, marked by the formulation and destruction of a long series of hypotheses as we have proceeded step by step toward a better knowledge of the secrets of the atmosphere. The past forty years has been especially rich in a kaleidoscopic series of developments in the views of those who are leading our thoughts toward the rational and true mechanics of the atmosphere. It is no disparagement to an honest seeker to be told that he has learned something, and has been forced to change an opinion within the past ten years, but it is, on the contrary, rather to his disparagement to confess that he has seen no reason to make any change in his former belief, notwithstanding the results of the researches of the many energetic physicists who have devoted their time and thoughts to meteorology.

We have been led to these thoughts by reading the latest pamphlet published by Faye of Paris, entitled "New Studies on Hurricanes, Cyclones, Waterspouts or Tornadoes," and have been forced to coincide with the sentiment of the following quotation from an admirable article in our cotemporary, Nature, of July 29:

> As a general rule it is a matter of perfect indifference to the ordinary purposes of life whether we hold a correct or an incorrect theory

in astronomy or meteorology. Life and commerce and navigation would go on the same whether we believed that the earth went round the sun, or the sun round the earth. But in this matter of tempests and cyclones, trade and commerce can be very adversely affected if we teach an incorrect theory of their origin and motion. A captain can only hope to escape from the danger with which they threaten him by localizing, with some precision, the situation of the inner vortex. To do this he has but one guide, the direction of the wind. The use he makes of this guide in inferring the position of the ship with reference to that of the storm center will be materially affected by the views he holds concerning the motion of the wind in a cyclonic storm. A rule must be devised for his guidance without ambiguity, and one that can be followed without hesitation. Piddington and the older meteorologists held that the movement of the wind in a cyclone was circular. In this view they are followed by Mr. Faye. The result of this belief was the enunciation of the rule of eight points expressed something in this way: With the face turned to the wind extend the right arm. In the Northern Hemisphere you will point in the direction of the storm center. This rule can be supported only by ignoring a great mass of recent observations. The rule asserts that the wind blows at right angles to the radius, but it has been shown over and over again that in true cyclones the winds are strongly inclined inwards, not directly to the center, but approaching it by a spiral. A more accurate rule has been deduced and is supported by weighty authorities, but not by Mr. Faye. In the Northern Hemisphere, with face to the wind, the direction of the center is from ten to eleven points to the right-hand side. To go back to the old rule of Piddington is a retrograde step, but the mischief does not end there. The distrust likely to be awakened in the mind of the seaman by the spectacle of disaccord among the scientific authorities can have the most disastrous results. The ordinary seaman asks for a clear and precise rule on which he can act without argument or question, while his whole attention is directed to the preservation of his ship. M. Faye is great authority. His name is one to conjure with, and it is not unlikely that the rules which he quotes with approval will be copied into English books by those who compile manuals of brief and ready directions for navigation, and in this way perpetuate an evil against which a mass of scientific evidence, collected in less accessible quarters, is powerless.

THE OBSERVATION OF HALOS.

The communication on a preceding page from the Rev. K. Schipps illustrates the remarks made in a recent number of the MONTHLY WEATHER REVIEW to the effect that meteorology offers innumerable fields of interest to the special observers, and there doubtless are a few in this country who, as students of physical or optical meteorology, will be glad to take up the subject of halos with the enthusiasm of the Halo Committee, represented by our learned correspondent. Students of meteorology will profit by a study of the treatment of this subject in the first and third volumes of the Traité d'Optique (Paris, 1893), by Mascart, the Director of the Meteorological Central Bureau of France. The ordinary rainbow is a well-known illustration of a solar halo, whose angular distance from the sun is from 138° to 140°, that is to say, about 40° or 42° from the anti-solar point or from the direction of the shadow of the observer. The general theory of the rainbow and its supernumerary arcs, as deduced from the wave theory of light, is given by Mascart (Chapter V), but a most elaborate investigation of the subject, together with a series of exact observations of rainbows, has just been published by Prof. J. Pernter, the newly-appointed successor to Prof. Dr. Hann as Director of the Central Institute for Meteorology and Terrestrial Magnetism at Vienna.

With regard to the names of the halo phenomena referred to by Dr. Schipps as proper to be used in the observers' condensed descriptions, the following list, compiled from Mascart's Treatise, will be helpful:

Corona, or glory. A circle of light or color surrounding the sun or moon or any other luminary, either celestial or terrestrial; the angular radius of such circles very rarely exceeds 5°; the largest that has yet been observed is the so-called Bishop's circle of about 15° radius, first described by Sereno Bishop of Honolulu, in connection with the haze due to the eruption of Krakatoa, August 27, 1883.

Anti-solar coronas or anti-lunar coronas. Similar small circles of light or bands of color surrounding the anti-solar point, and seen with especial beauty when, from a mountain top or a balloon, the observer's shadow is cast upon the clouds, and sometimes when it is simply cast upon a meadow covered with dewdrops.

Shadow beams, or perspective beams, or solar beams, or beams of light and shade. These beams, due to the shadows of clouds in the sky, or of mountains and terrestrial objects when the sun is below the horizon, appear to converge toward the solar and the anti-solar points, and are widest apart in the region perpendicular to the line joining the sun with the observer. They are, in fact, parallel with each other, and the convergence is only an illusion of perspective.

Primary rainbow. A halo of 40° or 42° radius from the anti-solar point, a brilliant circle of spectrum colors.

Secondary bow, or secondary rainbow. A halo of feebler light than the primary rainbow, and having a larger radius, viz, from 50° to 54° from the anti-solar point. The secondary rainbow is sometimes called the reflected bow as though it were the reflection of the primary, but this is not proper.

Tertiary rainbow. A halo having a radius of 41° from the sun; quarternary rainbow, a halo of 44° from the sun; quinary rainbow, a halo of 54° from the anti-solar point. The 3d, 4th, and 5th orders of rainbow are too feeble to be ordinarily observed.

Supernumerary arcs. The colored fringes that border almost every system of rainbow colors, and especially on the inside of the secondary rainbow.

Reflected halos or reflected bows. These are sometimes seen by reflection, properly so called, from the smooth surface of rivers or lakes.

The white rainbow. A halo of between 33° and 42° radius from the anti-sun, described first by Mariott, but more frequently known as Ulloa's circle.

The peculiarities of all halos depend upon the size of the particles or drops of water, the uniformity in size and shape, the number of reflections within the drops, and the mutual distance of the drops or particles from each other. Ulloa's white rainbow appears to be formed, according to Mascart, by the overlapping of bows formed by a mixture of drops of all sizes.

The second set of optical phenomena are due to the presence of crystals of ice, hexagonal prisms, flat plates, and hexagonal pyramids, either alone or in combination with drops of water. The optical phenomena due to these may be designated by the following among other names:

Anti-sun or anthelion. The bright spot or point directly opposite the sun, or directly in the line of the shadow of the observer's head.

Halo of 22° radius from the sun.

Halo of 46° radius from the sun.

The tail of the halo; a projection attached to the halo of 22°, and also to the halo of 46°.

Parhelic circle. A horizontal white band passing through the sun and sometimes entirely around the heavens parallel to the horizon.

Parhelion of 22°. A bright spot on the parhelic circle 22° to the right and left of the sun.

Tail of the parhelion. A short extension of the bright light from the parhelion, or mock, or false sun, extending vertically or horizontally.

Parhelion of 46°. The bright spot 46° from the sun at the intersection of the halo of 46° with the parhelic circle. This parhelion also has a tail streaming along both its intersecting circles, especially the halo circle.

Paranthelia. The mock suns that appear when the true sun is very near the horizon and which can appear in the parhelic circle on either side of the anthelion and at about