mountains. Sometimes they are manufactured articles, stones or blocks of wood cut into some shape which has a meaning either obvious or traditional.

The universality of this tendency to connect some material objects with religious worship, and the immense variety of modes in which this tendency has been manifested, is a fact which receives a full and adequate explanation in our natural disposition to conceive of all Personal Agencies as living in some form and in some place, or as having some other special connection with particular things in Nature. Nor is it difficult to understand how the embodiments, or the symbols, or the abodes, which may be imagined and devised by men, will vary according as their mental condition has been developed in a good or in a wrong direction. And as these imaginings and devices are never, as we see them now among savages, the work of any one generation of men, but are the accumulated inheritance of many generations, all existing systems of worship among them must be regarded as presumably very wide departures from the conceptions which were primeval. And this presumption gains additional force when we observe the distinction which exists between the fundamental conceptions of religious belief and the forms of worship which have come to be the expression and embodiment of these. In the Religion of the highest and best races, in Christianity itself, we know the wide difference which obtains between the theology of the Church and the popular superstitions which have been developed under it. These superstitions may be, and often are, of the grossest kind. They may be indeed, and in many cases are known to be, vestiges of Pagan worship which have survived all religious revolutions and reforms; but in other cases they are the natural and legitimate development of some erroneous belief accepted as part of the Christian creed. Here, as elsewhere, Reason working on false data has been, as under such conditions it must always be, the great agent in degradation and decay.

METEOROLOGICAL ELECTRICITY.

Ciel et Terre gives a description of a cyclone which passed over Japan on the night of the 3d or 4th of October, 1880. At Tokio a rapidity of 45 metres per second has been observed, but this had only a rapidity of 10 metres; its diameter was not very considerable, 240 kilometres. The fall of the barometer, though rapid, was far from being as prompt as that occurring eight days before on the coasts of the Island of Formosa, where a depression of 73 millimetres in 4 hours, or 18 millimetres per hour, was observed. These indicate that the old theory of whirlwinds is perfectly useless to account for meteorological phenomena.

THE APERTURE OF MICROSCOPE-OBJECTIVES.

The last number of the *Journal* of the Royal Microscopical Society is largely occupied with a discussion of this question by Prof. E. Abbe, of Jena, and Mr. Frank Crisp, one of the secretaries of the Society.

The subject appears to have been again brought up by a paper by Mr. G. Shadbolt (President of the Society in 1856), who claimed to have "demonstrated beyond dispute that no objective could have an aperture of any kind in excess of 180° angular in air." The grounds on which Mr. Shadbolt rested his demonstration are disposed of in detail in the papers now published; but with this aspect of the matter we do not propose to deal, confining ourselves to the more general consideration of the subject, apart from any controversial matter.

The proper definition of the aperture of a microscope-objective was, for a long time, as is well known, a very vexed one among microscopists. The astronomer has always a ready definition for the telescope, the aperture of which was simply estimated by the absolute diameter of the object-glass. No such absolute measure is, however, possible in the case of the microscope-objective, as the lenses of which it is composed vary in diameter within considerable limits, and the larger lens is by no means the larger aperture, as is readily seen by the comparison of the large lenses of the low powers with the small lenses of the high powers, which yet much exceed the former in aperture.

In consequence of this difficulty, the angle of the pencil, as it emanates from the object, and prior to its transmission through the objective to the image, came to be very generally considered as the proper measure of the aperture of the objective. This was at a time when dry or air objectives were generally known, immersion objectives not having been brought into ordinary use.

But even with air objectives the angle of the radiant pencil did not afford a true comparison, which could only be made by the *sines* of the angles; but when immersion objectives were originated—that is, objectives in which water or oil replaced the air in front of the objective—the use of the angles became very misleading, for now three angles might all have the same number of degrees and yet denote very different values, according as they are in air, water, or oil.

It therefore became necessary to find a substitute for the angles in the comparison of apertures; for although it was no doubt possible to bear in mind that 82° in air was less aperture than 82° in water, and the latter less than 82° in oil, yet the use of the same figures inevitably tended to produce confusion in the minds of microscopists —so much so that it was stoutly maintained by one party that the apertures in the three cases we have referred to were identical because the angles were the same.

A solution of the difficulty was discovered by Professor Abbe, who pointed out that the true definition of aperture (in its legitimate meaning of "opening") was obtained when we compared the diameter of the pencil emerging from the objective with the focal length of the objective.

It will be desirable to explain somewhat more in detail how this conclusion is arrived at—as given in Prof. Abbe's paper.

Taking in the first case a *single*-lens microscope, the number of rays admitted within one meridional plane of the lens evidently increases as the diameter of the lens (all other circumstances remaining the same), for in the microscope we have at the back of the lens the same circumstances as are in front in the case of the telescope. The larger or smaller number of emergent rays will, therefore, be properly measured by the clear diameter; and as no rays can *emerge* that have not first been *admitted*, this must also give the measure of the admitted rays.

Suppose now that the focal lengths of the lenses compared are not the same,—what then is the proper measure of the rays admitted?

If the two lenses have equal openings but different focal lengths, they transmit the same number of rays to equal areas of an image at a definite distance, because they would admit the same number if an object were substituted for the image—that is, if the lens were used as a telescope-objective. But as the focal lengths are different the amplification of the images is different also, and equal areas of these images correspond to different areas of the object from which the rays are collected. Therefore, the higher-power lens, with the same opening as the lower power, will admit a *greater* number of rays in all from the same object because it admits the *same* number as the latter from a *smaller* portion of the object. Thus if the focal lengths of the two lenses are as 2 : 1, and the first amplifies N diameters, the second will amplify 2 N with the same distance of the image, so that the rays which are collected *to* a given field of 1 mm. diameter of the image are admitted *from* a field of $\frac{1}{N}$ mm. in the first case and of $\frac{1}{2N}$ mm. in the second. Inasmuch as the "opening" of the objective is estimated by the diameter (and not by the area) the higher-power lens admits *twice* as many rays as the lower power, because it admits the *same* number from a field of *half* the diameter, and in general the admission of rays with the same opening, but different powers, must be in the inverse ratio of the focal lengths.

In the case of the single lens, therefore, its aperture must be determined by *the ratio between the clear opening and the focal length*, in order to define the same thing as is denoted in the telescope by the *absolute* opening.

Dealing with a *compound objective*, the same considerations obviously apply, substituting, however, for the clear opening of the single lens, the diameter of the pencil at its emergence from the black lens of the objective —that is, its clear effective diameter.

All equally holds good, whether the medium in which the objective is placed is the same in the case of the two objectives or different, as an alteration of the medium makes no difference in the power.

Thus we arrive at the general proposition for all kinds of objectives. 1st. When the power is the same, the admission of rays varies with the diameter of the pencil at its emergence. 2nd. When the powers are different the *same admission* requires *different openings* in the proportion of the focal lengths, or, conversely, with the *same opening the admission is in inverse proportion* to the focal length—that is, the objective which has the wider pencil relatively to its focal length has the larger aperture.

Thus we see that, just as in the telescope, the absolute diameter of the object-glass defines the aperture, so in the microscope, the ratio between the utilized diameter of the back lens and the focal length of the objective defines its aperture.

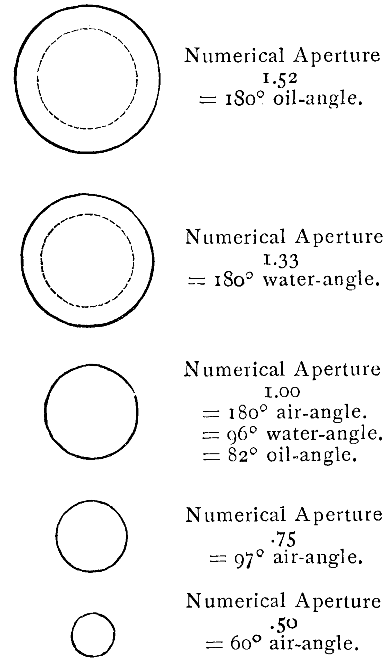
This definition is clearly a definition of aperture in its primary and only legitimate meaning as "opening"—that is, the capacity of the objective for admitting rays from the object and transmitting them to the image; and it at once solves the difficulty which has always been involved in the consideration of the apertures of immersion objectives.

So long as the angles were taken as the proper expression of aperture, it was difficult for those who were not well versed in optical matters to avoid regarding an angle of 180° in air as the maximum aperture that any objective could attain. Hence water-immersion objectives of 96° and oil-immersion objectives of 82° were looked upon as being of much *less* aperture than a dry objective of 180°, whilst, in fact, they are all *equal*—that is, they all transmit the same rays from the object to the image. Therefore, 180° in water and 180° in oil are unequal, and both are much larger apertures than the 180° which is the maximum that the air objective can transmit.

If we compare a series of dry and oil-immersion objectives, and, commencing with very small air-angles, progress up to 180° air-angle, then taking an oil-immersion of 82° and progressing again to 180° oil-angle, the ratio of opening to power progresses continually also, and attains its maximum, not in the case of the air-angle of 180° (when it is exactly equivalent to the oil-angle of 82°), but is greatest at the oil-angle of 180°.

If we assume the objectives to have the same power throughout, we get rid of one of the factors of the ratio, and we have only to compare the diameters of the emergent beams, and can represent their relations by diagrams. Our figure (which is taken from Mr. Crisp's paper) illustrates five cases of different apertures of ¼in. objectives—viz., those of dry objectives of 60°, 97° and 180° air-angle, a water-immersion of 180° water-angle, and an oil-immersion of 180° oil-angle. The inner dotted circles in the two latter cases are of the same size as that corresponding to the 180° air angle.*

RELATIVE DIAMETERS OF THE (UTILIZED) BACK-LENSES OF VARIOUS DRY AND IMMERSION OBJECTIVES OF THE SAME POWER (¼) FROM AN AIR-ANGLE OF 60° TO AN OIL-ANGLE OF 180°.



A dry objective of the full maximum air-angle of 180° is only able (whether the first surface is plane or concave) to utilise a diameter of back lens equal to twice the focal length, while an immersion lens of even only 100° (in glass) requires and utilises a *larger* diameter, *i. e.*, it is able to transmit more rays from the object to the image than *any* dry objective is capable of transmitting. Whenever the angle of an immersion lens exceeds twice the critical angle for the immersion-fluid, *i. e.*, 96° for water or 82° for oil, its aperture is in excess of that of a dry objective of 180°.

Having settled the principle, it was still necessary, however, to find a proper notation for comparing apertures. The astronomer can compare the apertures of his various telescopes by simply expressing them in inches; but this is obviously not available to the microscopist, who has to deal with the *ratio* of two varying quantities.

Prof. Abbe here again conferred a boon upon microscopists by his discovery (in 1873, independently confirmed by Prof. Helmholtz shortly afterwards) that a general relation existed between the pencil admitted into the front of the objective and that emerging from the back of the objective, so that the ratio of the semi-diameter of the emergent pencil to the focal length of the objective could be expressed by the sine of half the angle of aperture (u) multiplied by the refractive index of the medium (n) in front of the objective, or n sin. u (n being 1.0 for air, 1.33 for water, and 1.5 for oil or balsam).

When, then, the values in any given cases of the expression n sin. u (which is known as the "numerical aperture") has been ascertained, the objectives are instantly compared as regards their aperture, and, more-

* The explanation of the mistaken supposition that the emergent beam is wider in the case of the immersion objectives because the immersion-fluid abolishes the refractive action of the first plane surface of the objective (which, in air, reduces all pencils to 80° within the glass), belongs rather to the controversial branch of the matter. It is, however, fully dealt with in the papers referred to.

over, as 180° in air is equal to 1.0 (since $n = 1.0$, and the sine of half 180° or 90° = 1.0), we see with equal readiness whether the aperture of the objective is smaller or larger than that corresponding to 180° in air.

Thus, suppose we desire to compare the relative apertures of three objectives, one a dry objective, the second a water-immersion, and the third an oil-immersion. These would be compared on the angular aperture view as, say, 74° air-angle, and 118° balsam-angle; so that a calculation must be worked out to arrive at a due appreciation of the actual relation between them. Applying, however, "numerical" aperture, which gives .60 for the dry objective, .90 for the water-immersion, and 1.30 for the oil-immersion, their relative apertures are immediately appreciated, and it is seen, for instance, that the aperture of the water-immersion is somewhat less than that of a dry objective of 180°, and that the aperture of the oil-immersion exceeds that of the latter by 30 .

When these considerations have been appreciated, the advantage possessed by immersion in comparison with dry objectives is no longer obscured. Instead of this advantage consisting merely in increased working distance or absence of correction-collar, it is seen that a wide-angled immersion objective has a larger aperture than a dry objective of the maximum angle of 180°; so that for any of the purposes for which aperture is desired, an immersion must necessarily be preferred to a dry objective.

The task of making an abstract of these papers was not a light one and we are indebted to the *English Mechanics* for the above résumé.

BOOKS RECEIVED.

DISCOVERY OF THE PREGLACIAL OUTLET OF THE BASIN OF LAKE ERIE INTO THAT OF LAKE ONTARIO; with notes on the Origin of our Lower Great Lakes. By PROF. J. W. SPENCER, B. A. Sc., Ph. D., F. G. S., Kings College, Windsor, N. S. 1881.

As one new branch of knowledge is raised to a science, there still seems to be some other rising to importance. For a long time the explanation of the Physical Features of America has been handed over to the rival Glacier and Iceberg theories, and though much good work has resulted, yet an almost unlimited amount of nonsense has been written, especially by the extreme or ultra-glacial school. During all these years comparatively little attention has been given to the subject of the river geology, more than that many buried channels have been recorded with but few attempts at the reduction of the abstract facts to a branch of Science. There has, however, been a very great difficulty, owing to the Preglacial valleys often being entirely obscured, or, if apparent, an absence of the knowledge of their depths has prevented generalization. In most of the cases recorded, the buried channels have not had courses greatly differing from those of modern times. It has been known for some time that the waters of most of the great lakes had southern outlets when at higher levels, and even to-day the drainage of Chicago passes to the Mississippi. It has been frequently suggested that Lake Ontario emptied by the Mohawk into the Hudson. This, however, was not the case. We are then compelled to place General G. K. Warren as the father of Fluviatile Geology, for he discovered that the Red River of the North (with Lake Winnipeg, the Saskatchewan, and other great rivers of the North West territories of Canada, as tributaries) discharged by the Minnesota river into the Mississippi, and thus produced a river to which no modern water is comparable. On further investigation Gen. Warren's views are found to require some modification, yet this does not detract from the position which may be fairly assigned to him. Dr. Newbury's observations in Ohio have also thrown much additional light on the subject, but a much more important work has been accomplished by Mr. J. F. Carll, of Pennsylvania, when from a careful study of the levels and borings for oil in that State, he discovered that the Upper Alleghany and several other rivers now flowing into the Ohio, formerly emptied into Lake Erie (or its basin).

But the most important contribution on the subject of Fluviatile Geology that has been made is the recent paper of the above title, by Professor Spencer, now of Kings College, Nova Scotia, but formerly residing in the lake region, in the Province of Ontario. The paper of the above title was read before the American Philosophical Society, of Philadelphia, and its publication will be found in the forthcoming proceedings of that Society. It is also being reprinted as an appendix to Report Q 4 of the Pennsylvania Survey, as shown by the maps which accompany the author's edition, of which we have just received a copy. The following is a synopsis of the principal points of the paper:

The Niagara escarpment bends abruptly at the western end of Lake Ontario, and has a height of about 500 feet above the lake. Through this limestone ridge the Dundas valley extends, and enters the extreme western end of the lake. At the narrowest portion of the valley the width is upwards of two miles, and the margins are those of the walls of a perfect *cañon*, 500 feet deep. But by boring near one of its margins, the buried channel is found to reach 227 feet below the surface of Lake Ontario, making a total depth of 743 feet, but with a computed depth in the central part of its course of not less than 1000 feet. The author first discovered that the ancient upper portion of the Grand River left its modern course south of Galt, and although a portion of the old bed is entirely obscured, yet by pursuing the course of the deep wells the ancient route can be traced through the drift to the western end of the Dundas *cañon* and Lake Ontario. In following up this subject Dr. Spencer discovered that the lower portion of the Grand River was formerly an outlet of the Erie basin, which discharged by a course from a point southward of Cayuga (Province of Ontario), and flowed to the westward of this town and entered the present valley, which is two miles wide and eighty feet deep, but underlaid deeply with drift. Westward of Seneca the ancient river left its modern course and passed into the Dundas valley. All these observations are elaborately worked out by levels, deep well borings, and deep ravines, with the one well in this course indicating a depth of 1000 feet of drift in the ancient valley, measuring from the limestone floor of the county.

The outlet of Lake Erie is directly opposite to that of the ancient Alleghany River.

Again, Dr. Spencer has made a study of the soundings of the lakes, and has discovered a long submerged escarpment extending along the southern side of Lake Ontario to near Oswego, at the foot of which the Ancient River from the Dundas Valley ran. The author has shown that an ancient, broad channel, extended from Lake Huron and entered Lake Erie between Port Stanley and Vienna, in the Canadian Province of Ontario. This channel has a marginal depth of 200 feet below Lake Erie, but with a probable depth sufficient to drain Lake Huron.

With regard to Lake Superior, Prof. Spencer shows that it formerly emptied into the northern end of Lake Michigan, and formed a river channel now represented by deep pot-holes. He brings forward some of the evidence showing that Lake Michigan emptied or was completely drained by the tributaries of the Mississippi, and that this lake was probably disconnected from Lake Huron. At the same time, he shows that Lake Superior (when it was at no higher level than at present) did not empty by the Green Bay and valley of the Fox and Wisconsin Rivers.

The author denies the hypothesis of the glacial origin of the Great Lakes, and brings forward strong evidence in support of his views. He correlates with his work and maps the buried channels discovered in Pennsylvania and