large, and the low retail price—threepence per dozen—shows how great the take has been.

It is clear, from the mere enumeration of the species named here, that there is great variety in the fish fauna of these islands; and, when the testimony of observers in all parts of the colony as to their immense numbers is taken into account, it is certain that from her fisheries New Zealand will yet reap an immense harvest.

BOOK-REVIEWS.

A Popular Treatise on the Winds: Comprising the General Motions of the Atmosphere, Monsoons, Cyclones, Tornadoes, Waterspouts, Hail-Storms, etc. By WILLIAM FERREL, M.A., Ph.D. New York, Wiley. 8°.

THOSE of us who, about to reach the twoscore prime of middle age, nevertheless feel a little hurt at the respect shown for our advanced years by a younger generation who call us old, may take comfort on realizing that the science of meteorology has been made over again by a man whose labors upon it began only when he had reached our measure of life. William Ferrel was born in 1817, a farmer's boy in Pennsylvania. He grew up in Virginia, dividing his time between the field and the rough country schoolhouse. A love for mathematics then led him into teaching, and afterwards to our Nautical Almanac Office. In 1856, at the age of thirty-nine, Maury's facts made him so dissatisfied with Maury's impossible theory of the winds, that, at the solicitation of a friend, he wrote an outline of what seemed to him a truer conception of the general circulation of the atmosphere; and with this essay the new school of mathematical meteorology began. A few years ago the appearance of Ferrel's "Recent Advances in Meteorology" gave occasion to state the outline of his theory,[1] in comparison with others generally in vogue. Another volume now allows another reference to this attractive subject.

This "Popular Treatise on the Winds" embodies the substance of a series of forty lectures delivered by Ferrel before a class of army officers of the Signal Service in February and March, 1886. It is now much expanded by deliberate statement of the fundamental principles of atmospheric rest and motion, and is illustrated by abundant citation of pertinent observations and records. The book is too serious, too severely argumentative, for general reading; but it will for a long time have no equal in our language as a volume to which teacher and student may make safe reference in the search for the solution of difficulties. The plan of the book may be judged by a brief review of its contents. It opens with preliminary chapters on the constitution and nature of the atmosphere, and on the motions of bodies relative to the earth's surface; the latter being a subject which Ferrel has made his own, and without which no safe step can be taken in the discussion of atmospheric movements. The third chapter discusses the theoretical circulation of an atmosphere lying on a rotating globe, and heated around the equator, deducing therefrom certain critical consequences, and confronting them with the facts as ascertained by observation. He must indeed be wanting in the scientific turn of mind who does not find mental entertainment in the logical order of investigation here traced out, quite apart from its bearing on the special science to which the book is devoted. Next follow a chapter on the climatic influences of the general circulation of the winds, in the production of wet and dry zones and of wet and dry mountain slopes, and in the determination of equable and variable temperatures on the west and east sides of continents, and another chapter on the monsoons, littoral breezes, and mountain and valley winds, by which the general terrestrial circulation is more or less broken up. Thus the first half of the book is occupied. The second half discusses those great travelling whirls known as cyclones, and the more local tornadoes and thunder-storms, on all of which the impress of Ferrel's methods is most clearly marked.

Through all this there runs a single theme. Some fact of occurrence calls for explanation. A fit explanation is devised, strictly in accord with a full knowledge of physical law, and its consequences are then deduced as minutely as may be. These are matched with the facts, and the validity of the theory is measured by the degree of correspondence then detected. No one can read such a work as this without feeling a distinct intellectual gain from the keen vigor of its methods.

There is one feature in Ferrel's theory of the atmospheric circulation that does not seem to be generally appreciated. We may perhaps best approach it through its misapprehension by certain commentators. Professor Supan, editor of *Petermann's Mitteilungen*, whose extended reviews give us the best means of keeping abreast with the advance of geography in all its branches, referred four years ago to Ferrel's theory in a notice of Sprung's

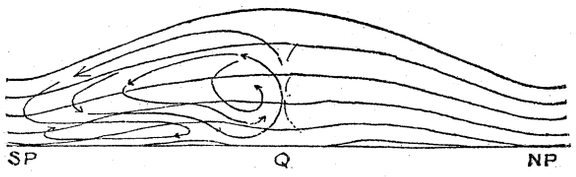

FIG. 1.

"Lehrbuch der Meteorologie." He said in effect that the distribution of atmospheric pressure was the control, not the result, of atmospheric motion; and that, as there is low pressure at the poles and high pressure at the tropics, the hypothetical return current from poles to equator cannot exist, for it would have to move against the barometric gradients.[1] The same question is asked by M. Léon Teisserenc de Bort, one of the specialists of the Bureau Central Météorologique de France. In an essay on the general circulation of the atmosphere,[2] this author says, "Mr. Ferrel does not explain the cause of the gradient that is directed toward the equator, and that is necessary for the return current from pole to equator, which he places at a middle altitude in the atmosphere. This gradient is the more difficult to explain, inasmuch as the pressure at sea-level decreases towards the pole, and as a similar decrease must exist aloft to determine the flow of the

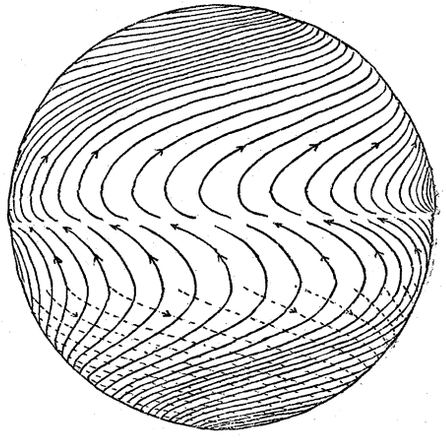

FIG. 2.

upper current from the equator." These criticisms appear reasonable enough at first sight, but this is because they fail to apprehend one of the essential points in Ferrel's theory. The case may be stated in brief as follows:—

Given a uniform distribution of temperature in the atmosphere, its imaginary isobaric surfaces will stand level, essentially equidistant. Given two adjacent regions, one maintained at a higher temperature than the other, the isobaric surfaces can no longer be level or parallel. A convectional interchanging motion will be established, as a consequence of which there will come to be a slight excess of pressure in the colder region. The isobaric surfaces, not parallel, but diverging from the region of cold and compressed air to the region of warm and expanded

[1] Science, iv. 1887.

[1] Petermann's Mitteilungen, Lit. Bericht., 1886.

[2] Ann. Bur. Centr. Mét., 1885, part. iv. Mét. Générale.

air, are no longer level: they are deformed into slanting positions, and the slant or gradient is directed toward the warm region in the lower atmosphere, and toward the cold region in the upper atmosphere. Thus far every one is willing to go: and, if it be desired to try the experiment on a class of intelligent scholars, some live interest in the question may be aroused by asking how far they are individually ready to assert that this simple abstract theory is applicable to the case of the earth; the warm region being the equator, where the mean annual pressure must therefore be low, and the cold region being either pole, where the pressure must be correspondingly high. No more salutory lesson can be given in the danger of the purely deductive method in the hands of others than the masters of a subject, for the high pressure that is confidently expected at the poles does not exist. The pressure there is lower than at the equator. The contradiction of theoretical deduction by well-ascertained fact is of the flattest kind, and the scholar may fairly be excused if for a time he loses faith in a theory that has led him into so blundering an expectation. But when he looks further, and finds that there is a belt of lower pressure at the equator than at the tropics, and that this belt migrates with the seasonal shifts of the heat equator, and that the continents unload their share of atmosphere somewhat in their summer season, it becomes apparent that the theory must be wrong chiefly by omission; and it may be readily shown that the omitted consideration is the effect of the earth's rotation. There are very few men in the world who have for themselves avoided this omission; and of these few, Professor Ferrel is the only one who has given the complete theory the full consideration that it deserves.

The fact that the interchanging convectional circulation of the atmosphere between the equator and the poles takes place upon an earth that rotates on its axis, requires the development of great eastward spiral polar whirls, and the centrifugal force of these whirls greatly deforms the simple arrangement of the isobaric surfaces that would be produced by differences of temperature alone; so greatly, indeed, that the theoretical high pressure of the poles is reversed to actual low pressure. In consequence of this, the gradients of nearly all the atmosphere are directed polewards, the only gradients that lead to the equator being in the lower atmosphere within the tropics, where we have the trade-winds. This may appear more clearly in Fig. 1, which represents a vertical meridional section of the atmosphere, greatly magnified vertically, from pole across the equator to pole; the meridian line being, for simplicity, straightened out from its true semicircular curve. The pressures at the surface are known by observation, being, on the average, about 29.9 at the equator, 30.1 a little outside of the tropics, and perhaps 29.0 at the poles. Remembering that the successive isobaric surfaces diverge from the cold polar regions towards the warm equatorial belt, a number of higher and higher surfaces may be drawn in section, and the prevailing poleward slope of the gradient is then made apparent.

Now, the question asked by Supan and Teisserenc de Bort is practically this: "How does the air, which flows toward the poles on the steep gradient of the upper current, manage to return to the equator against the poleward gradients of the lower levels?" This is as if they asked, "How does the ocean stand thirteen miles higher (i.e., farther from the earth's centre) at the equator than at the poles, instead of at once rushing tumultuously poleward?"

The low pressure at the poles is the indirect product of the initial meridional convectional circulation between poles and equator, and the deformation of the simple convectional gradients thus introduced can never go so far as to stop the convectional motion by preventing the return of the lower current to the equator. The great velocity and consequent great centrifugal force attained by the upper current, as it swings around the pole on the steep upper gradients, enable it to run obliquely against the weaker lower gradients as soon as it encounters them in the descending portion of its convectional circuit. That is the essence of the whole affair, though it may be stated in different ways, from words to formulæ. Perhaps a simpler way of putting it is this. The difficulty comes from thinking that the lower isobaric surfaces slope toward the pole. But it must be remembered that slopes and levels are determined by the local direction of gravity, not by distance from the earth's centre; that the local direction of gravity is determined by the local value of the centrifugal force arising from axial rotation, and the velocity of axial rotation depends on whether the body that is under discussion goes around the axis once in twenty-four hours, as we do who live on the earth's surface, or in a decidedly less time, as the eastward winds do. If the earth had no rotation, its present level surfaces would be called poleward slopes. The winds which move eastward must regard the sea-level as an equatorward slope; and the fast winds of the great eastward whirls around the poles must regard even the lower gradients of the atmosphere as slopes directed toward the equator, and not toward the pole. It is only the lower winds, whose velocity is weakened by surface friction, that have the same opinion of the lower gradients as we have, and obey them by moving obliquely toward the pole. This is not a matter that needs mathematical statement for its demonstration. The rational conception of the process, on which the validity of any mathematical treatment must be based, is sufficient to demonstrate that the isobaric surfaces, whose arrangement is determined simply by differences of temperature, cannot agree in position with those which are, as it were, deformed by the introduction of the deflective forces that arise from the earth's rotation; and to demonstrate, further, that the deformation thus introduced can never go so far as absolutely to stop, although it may greatly retard, the meridional or convectional components of motion, on whose persistence all the other motions depend. The reader of the "Popular Treatise on the Winds" can come to no other conclusion than that the essential nature of the circulation of the winds is such as is here outlined; and the doubts raised by Supan and others will then not be regarded as objections to Ferrel's theory.

The actual circulation of the winds over continents and oceans is greatly complicated by seasonal and topographic influences, as well as by the presence of numerous cyclonic storms, marching in continuous procession around either pole. But the ideal planetary circulation is relatively simple; and, as the graphic illustration of its course is seldom given in more than highly diagrammatic forms, we venture to introduce here a more carefully drawn view of it, the upper winds being exhibited in the northern hemisphere, and the hypothetical return current of middle elevation being drawn on the southern, while the surface winds are in dotted lines beneath. There is much that is hypothetical in this; but it is as a whole well borne out by actual observation. One of the questions that is still open is the latitude at which the upper poleward overflow from the equator has a directly poleward motion. The latitude certainly varies with the altitude, but it does not appear to be more than ten degrees north or south of the equator: for on a poleward gradient, and with a right-hand deflection, both of which are undoubted, the upper overflow cannot long maintain the westward component of motion that it possesses above the equator; and, as a matter of fact, the oblique pole-eastward motion of the overflow has often been observed in the drifting of clouds and in the wind on mountain-tops in the so-called "anti-trade."

The reader must not imagine that all of Professor Ferrel's book is occupied with theoretical discussions. The citation of appropriate facts is plentiful and well selected; quotations are made at length from various sources; and although the winds are, by the title of the work, its main theme, one needs but small acquaintance with meteorology to know that nearly all of the science may be fairly presented under this heading. It is most natural that a course in meteorology should begin and end with a discussion of the circulation of the winds; for pretty much every thing meteorological is, like the deformation of the polar gradients, more or less closely a sequence of the motion of the atmosphere. When the educational value of the study of meteorology is more widely appreciated, as it must be when more of our teachers are familiar with such works as this one of Ferrel's, it may come to be true, as an eminent Scottish meteorologist some twenty years ago imagined it was already at that time, that "in the schools of the United States of America,

meteorological observations and the keeping of meteorological registers form a part of the common education of the people.''

W. M. D.

NOTES AND NEWS.

AT the Franklin Institute, Philadelphia, Monday evening, Feb. 17, Mr. George F. Kunz of New York lectured on precious stones, showing lantern illustrations of the Paris Exposition.

— The next meeting of the American Branch of the Society for Psychical Research will be held at the rooms of the Boston Society of Natural History, corner of Berkeley and Boylston Streets on Tuesday, March 4, at 8 P.M. Professor William James will preside. An abridgment of papers by Mr. Frank Podmore and Mr. F. W. H. Myers, on ''Phantasms of the Dead,'' will be read by the secretary. No admittance except by ticket.

— The New York Mineralogical Club made an excursion on Feb. 22 to Philadelphia, to visit one of the principal mineral localities and some important collections. Leaving by the 8 A.M. express, they reached Broad Street Station at 10.10. Here the party was met by representatives of the Mineralogical Section of the Philadelphia Academy. Thence, under the guidance of Mr. Theodore D. Rand, they went by rail to the Soapstone Quarry, on the Schuylkill, crossing exposures in the vicinity of the quarry, of most of the rocks of Philadelphia. Returning to Broad Street between 1 and 2 P.M., they visited the Academy of Natural Sciences during the afternoon, and the celebrated cabinet of Mr. Clarence S. Bement. The return to New York was by the train leaving Broad Street at 8.30 P.M.

— In the ''Third Annual Report of the Henry Draper Memorial,'' attention is called to the fact that the K line in the spectrum of ζ Ursæ Majoris occasionally appears double. The spectrum of this star has been photographed at the Harvard College Observatory on seventy nights, and a careful study of the results has been made by Miss A. C. Maury, a niece of Dr. Draper. The K line is clearly seen to be double in the photographs taken on March 29, 1887, on May 17, 1889, and on Aug. 27 and 28, 1889. An examination of all the plates leads to the belief that the line is double at intervals of fifty-two days, beginning March 27, 1887, and that for several days before and after these dates it presents a hazy appearance. The doubling of the line was predicted for Oct. 18, 1889, but only partially verified. The star was, however, low, and only three prisms could be used, while the usual number was four. The only satisfactory explanation of this phenomenon as yet proposed is that the brighter component of this star is itself a double star, having components nearly equal in brightness, and too close to have been separated as yet visually; also that the time of revolution of the system is one hundred and four days. When one component is approaching the earth, all the lines in its spectrum will be moved toward the blue end, while all the lines in the spectrum of the other component will be moved by an equal amount in the opposite direction if their masses are equal. Each line will thus be separated into two. The predicted doubling of the lines of ζ Ursæ Majoris on Dec. 8 was confirmed on that day by each of three photographs. Two more stars have been found showing a similar periodicity.

— The *Engineer* of Jan. 31 contains a leading article on color-blind engine-drivers, and it is interesting to note what the leading technical journal has to say on the subject: ''We do not say that no accident was ever brought about by the inability of a driver to distinguish between a green light and a red one, but we can say that nothing of such an accident is to be met with in the Board of Trade Reports.'' Our contemporary is of opinion that the testing of the sight of locomotive men should be made under working conditions, i.e., with actual signal lights.

— We learn from *Nature* of Feb. 6 that a paper on mortality from snake-bite in the district of Ratnagherry was read before the Bombay Natural History Society by Mr. Vidal, of the Bombay Civil Service. Many of the deaths in that district are, he says, due to a small and insignificant-looking snake, called ''foorsa'' by the natives. It is a viper rarely more than a foot long, and is so sluggish that it does not move out of the way till trodden on. Thus it is much more dangerous than the stronger and fiercer cobra.

— A new and very simple method of synthesizing indigo has been discovered by Dr. Flimm of Darmstadt (*Ber. deut. chem. Ges.*, No. 1, 1890, p. 57). In studying the action of caustic alkalies upon the monobromine derivative of acetanilide, $C_6H_5.NH.CO.CH_2Br$, a solid melting at 131.5°, it was found, that, when this substance was fused with caustic potash, a product was obtained which at once gave an indigo-blue color on the addition of water, and quite a considerable quantity of a blue solid resembling indigo separated out. The best mode of carrying out the operation, according to *Nature*, is described by Dr. Flimm as follows: ''The monobromacetanilide is carefully mixed with dry caustic potash in a mortar, and the mixture introduced into a retort and heated rapidly until a homogeneous reddish-brown melt is obtained. This is subsequently dissolved in water, and a little ammonia or ammonium-chloride solution added, when the liquid immediately becomes colored green, which color rapidly changes into a dark blue; and in a short time the blue coloring-matter is for the most part deposited upon the bottom of the vessel in which the operation is performed. The fused mass may also conveniently be dissolved in dilute hydrochloric acid, and a little ferric chloride added, when the formation of indigo takes place immediately. The collected blue coloring-matter may be readily obtained pure by washing first with dilute hydrochloric acid, and afterwards with alcohol.'' That this blue substance was really common indigo was proved by the fact that it yielded several of the most characteristic reactions of indigotin, such as solubility in aniline, paraffine, and chloroform; its sublimation; and the formation of sulphonic acids, which gave similar changes of color with nitric acid to those of indigotin. The final proof was afforded by its reduction to indigo white, and re-oxidation to indigo blue by exposure to air. Moreover, the absorption spectrum of the coloring-matter was found to be identical with the well-known absorption spectrum of indigo: hence there can be no doubt that indigo is really formed by this very simple process.

—A recent telegram from Tashkent, says *Nature*, announced that Col. Pevtsoff and M. Roborovsky had discovered a convenient pass to the north-western part of Thibet, from Nia, and had amounted to the great tableland. The plateau has there an altitude of 12,000 feet above the sea, and the country round is desolate and uninhabited, while towards the south the plateau is well watered and wooded. The Tashkent telegram is so expressed that it might be supposed to mean that two separate passes had been discoverd by the two explorers. But the news received from the expedition at St. Petersburg on Dec. 26, and dated Oct. 27, shows that both explorers proposed to leave the oasis of Keria (100 miles to the east of Khotan) on the next day, for Nia (65 miles farther east), and there to search for a passage across the border-ridge which received from Prjevalsky the name of the ''Russian Ridge.'' This immense snow-clad chain separates the deserts of eastern Turkestan from the trapezoidal space, the interior of which is quite unknown yet, and which is bordered by the ''Russian Ridge'' and the Altyn-tagh, in the north-west; the ridges of Tsaidam and those named by Prjevalsky ''Columbus'' and ''Marco-Polo,'' in the north-east; the highlands (explored by Prjevalsky in 1879–80) at the sources of the Blue River, in the south-east; and a long, yet unnamed ridge, which seems to be a prolongation of the Tan-la, in the south-west. The pass leading to that plateau from Nia, and now discovered by the Russian expedition, is situated some 80 miles to the east of the well-known pass across the Kuen-lun Mountains, which leads from southern Khotan to Lake Yashi-kul. M. Roborovsky's intention is evidently next to move up the Tchertchen River, and to endeavor to reach the ridges ''Moscow'' and ''Lake Unfreezing'' (11,700 feet high), which were visited by Prjevalsky from the east during his last journey. Having succeeded in finding a pass to Thibet in the south of Nia, Col. Pevtsoff proposes, as soon as the spring comes, to proceed himself by this pass to the tableland, while M. Roborovsky probably will be despatched