SOME NEW BOOKS.

What we Know About the Sun.

No better illustration could be given of the history of science, its rise, its methods, its stages, and its grandest triumphs, than is afforded by the progress of knowledge concerning that most familiar of all objects, the great luminary of day. Everybody knew, from the beginning, that it changed its observed positions, apparently revolving around the earth, and rising and falling in the sky at different seasons; and everybody also knew that it exerted a powerful influence over life upon the earth. But this was the common form of knowledge, vague and crude, yet having a basis of fact and certainty, and therefore containing the germs of science; and as with all the other familiar objects of nature, these germs lay dormant in the general mind for ages.

The celestial luminaries occupied the attention of the thoughtful in very early times, and the oldest of the sciences is astronomy. The first simple task was to watch the panorama of the sky, and note the positions and movements of the heavenly bodies. This gave rise to the first stage of astronomical science, which is known as Formal Astronomy. Observations of the changes of place of celestial bodies were recorded and accumulated, and led to generalized ideas concerning their motions. We owe formal astronomy to the old active-minded Greeks, who worked it out systematically, and accumulated data for reasoning, by which large theoretical notions of the nature of the celestial movements were framed. Hipparchus, in the second century before Christ, classified and catalogued the stars, and discovered the retrograde motion of the equinoctial points, or what is known as "the procession of the equinoxes." His pupil, Ptolemy, invented the ingenious system of epicycles, to account for the planetary movements. His theory assumes the earth to be the centre around which the sun and planets revolve, and this view prevailed until the time of Copernicus. The Ptolemaic system had served to combine and represent many observations and much truth, and it constituted a most important stage in the growth of the science; but its fundamental idea was subverted by Copernicus, who showed early in the sixteenth century that the sun is the real centre of the planetary revolutions. The overthrow of the geocentric system and the establishment of the heliocentric theory formed a great epoch in the progress of formal astronomy.

But the time had now come when a new order of ideas was to be introduced into the science, and a new branch of astronomy created. As the attention of thinking men was more and more turned to the phenomena of nature, they began to study the problem of forces and causes in the production of terrestrial effects. Applying those ideas to the heavens, they inquired how the celestial motions are produced, and this direction of study gave rise to Physical Astronomy. The planetary motions were to be resolved and explained by the experimental laws of motion. Galileo and Kepler prepared the way for Newton, whose glory it was to establish the great truth that the law of falling bodies upon the earth applies also to the moon and the planets, and is nothing less than a universal principle of matter. The demonstration of the law of gravity was a triumph of physical astronomy, and constitutes the second great epoch in the progress of astronomical science. Formal astronomy had fixed the place of the sun, and physical astronomy had established its power as the ruler of the planetary system.

Thus far astronomers had been occupied only with motions and their causes and laws. Celestial and terrestrial phenomena were unified in their dynamical aspects, and astronomy firmly planted upon a physical basis. But another great step still remained to be taken, though as yet there had not been the slightest preparation for it. The question was, As to the nature of the heavenly bodies themselves; what are they made of? How are they constituted? Are they like the earth, and like each other, or what are their material peculiarities? This problem was as yet closed to science. On grounds of analogy it was maintained that worlds are inhabited; but this was, of course, pure speculation. As the telescope slowly improved, something became known of what may be called the planetary physiognomies, but not the slightest light was thrown upon their material constitution. Chemistry is the science which gives account of the different kinds of matter and their intimate interactions; but this science had not yet emerged. Newton was an alchemist, and himself worked at the task of transmuting the cheaper metals into gold. And even when chemistry had advanced to a high degree of perfection, nobody dreamed that it could ever be extended to the heavenly bodies. So late as 1842 such a master of thought as Comte, in dealing with the philosophy of science, laid it down as an axiom that we can only determine the forms, distances, and movements of the celestial bodies, but can never study, by any means, their chemical composition.

Setting limits to science, however, has always proved an unsafe proceeding. Comte's statement has been falsified on a great scale. That which he declared to be forever impossible has already made a new epoch in astronomy; and the work was, in fact, well under way at the time Comte made his statement. Dr. John W. Draper of New York was even then laying the foundations of spectrum analysis. We have now an astronomical chemistry, based upon experiment, which is just as real and positive as terrestrial chemistry, and which has been so perfected, and so extensively and successfully applied, as to open a world of new phenomena and constitute a third great epoch in the progress of this science. Physical astronomy had demonstrated the dynamic unity of the universe; chemical astronomy has now demonstrated, with equal certainty, its material unity. This last conquest belongs entirely to the present age. In regard to the constitution of the sun, the last twenty-five years has given us a thousand times more real knowledge than had ever before been gathered.

The interest awakened by recent researches and their splendid results, has created the demand for a new exposition of the subject. Prof. YOUNG of Princeton has contributed a volume on *The Sun* to Appleton's "International Scientific Series," which is written from this point of view, and is an admirable representation of the new epoch of solar knowledge. Its author has himself had an eminent share in working out the recent discoveries pertaining to the solar constitution; and though not yet 50 years old, he has participated in the whole series of investigations, which will make the present period memorable in the future history of science. Of the execution of his book it is impossible to speak too highly. He writes from the familiarity of first-hand knowledge, and his work will be especially appreciated on account of the thorough trustworthiness of his statements. He has written, not so much for men of science as for intelligent readers, who have a general interest in scientific subjects, and the exposition is wonderfully clear and attractive. We have no intention here of reviewing his book, but propose simply to glean from his pages a few of their more striking results, so as to convey some idea of the present state of solar knowledge and of the real grandeur of solar phenomena.

The first question that naturally arises about the sun is, How far is it away from us? and this is, besides, the most fundamental question in general astronomy, and is as difficult as it is important. The distance of the sun from the earth is, of course, the half diameter or radius of the earth's orbit. This radius is the base line by which every other celestial distance is measured, excepting only that of the moon. Any error in this base line, therefore, propagates itself in all directions, and falsifies every measured line, the distance of every star, the radius of every orbit, and the diameter of every planet. All the calculations of the masses of the heavenly bodies depend upon the estimate of the sun's distance from the earth, and this distance generally enters into the computations by its cube, so that any error becomes magnified threefold. One per cent. of uncertainty in the sun's distance implies more than three per cent. of uncertainty in relation to every celestial mass and every cosmical force. Again, when time is taken into account, the effects of this error accumulate with great rapidity. If we knew exactly the sun's distance from the earth, we could predict exactly the course of celestial movement for all future time, and reproduce for all past time the conditions of planetary orbits and the situations and relations of planetary bodies. Such questions have actually been forced upon us by geology. The problem of glacial periods and the past life-history of the earth are now seen to be involved with that of the varying eccentricity of the earth's orbit in secular periods. "If, for instance, we should find, as the result of calculation with the received data, that two millions of years ago the eccentricity of the earth's orbit was at a maximum, and the perihelion so placed that the sun was nearest during the northern winter (a condition of affairs which it was thought would produce a glacial epoch in the southern hemisphere), it might easily happen that our results would be exactly contrary to the truth, and that the state of affairs indicated did not occur within half a million years of the specified date, and all because, in our calculation, the sun's distance, or solar parallax, by which it is measured, was assumed half of one per cent. too great or too small." The distance of the sun depends upon the accurate determination of the solar parallax, that is, the angular semi-diameter of the earth, as seen from the sun. The dimensions of the earth have been found with great accuracy, its semi-diameter being known within probably two hundred feet, one way or the other. But although this base line is nearly 4,000 miles long, so far away is the sun that the astronomer is in the predicament of a surveyor who, having to measure the distance of an object ten miles off, finds himself restricted to a base of less than five feet. The solar parallax has been determined to within a tenth of a second of an arc, but this tenth of a second of doubtfulness is more than one-hundredth of the whole. Although it is no more than the angle subtended by a single hair at a distance of nearly eight hundred feet, yet a variation of one-twentieth of a second either way would make a difference in the distance of the sun of half a million of miles. The problem cannot be solved by direct observations, but it has been proximately solved by a combination of indirect methods. All the evidence at present attainable makes the distance of the sun from the earth 92,885,000 miles, with a probable error of one-quarter of one per cent., or 225,000 miles.

But it is one thing to state these figures, and quite another to understand what they mean. Prof. Young is at the pains to translate them into the terms of common experience, so that they may be partially realized. He says: "If one were to try to walk such a distance, supposing that he could walk four miles an hour, and keep it up for 10 hours every day, it would take 68½ years to make a single million of miles, and more than 6,300 years to traverse the whole. If some celestial railway could be imagined, the journey to the sun, even if our trains ran 60 miles an hour, day and night, and without a stop, would require over 175 years. Sensation, even, would not travel so far in a human lifetime. To borrow the curious illustration of Prof. Mendenhall, if we could imagine an infant with an arm long enough to enable him to touch the sun and burn himself, he would die of old age before the pain could reach him, since, according to the experiments of Helmholtz and others, a nervous shock is communicated only at the rate of about 100 feet per second, or 1,637 miles a day, and would need more than 150 years to make the journey. Sound would do it in about fourteen years if it could be transmitted through celestial space, and a cannon ball in about nine, if it were to move uniformly with the same speed as when it left the muzzle of the gun. If the earth could be suddenly stopped in her orbit and allowed to fall unobstructed toward the sun, under the accelerating influence of his attraction she would reach the centre in about four months. I have said if she could be stopped, but such is the compass of her orbit that to make its circuit in a year she has to move nearly nineteen miles a second, or more than fifty times faster than the swiftest rifle ball, and in moving twenty miles her path deviates from perfect straightness by less than one-eighth of an inch."

The distance of the sun being given, and its angular diameter measured, we have the data for deducing its dimensions, although the combined errors of both these elements give uncertainty to the figures attained. The sun's linear diameter, however, is set down as 866,400 miles, although it may vary from that three or four thousand miles either way. The polar and equatorial diameters are the same, the sun's rotation on its axis once in twenty-five days giving rise to no sensible polar compression.

Here, again, the magnitude is so vast as to have no meaning in its bald numerical expression; and here, again, Prof. Young helps us out by concrete illustrations. The traveller who would make the circuit of the world in eighty days would require nearly twenty-four years to circumnavigate the sun. The sun's surface is nearly 12,000 times, and its volume or bulk more than 1,300,000 times greater than that of the earth. If the earth is represented by a three-inch globe, the sun, on the same scale, will be more than twenty-seven feet in diameter, and its distance 3,000 feet. If the sun were hollow, and the earth at its centre, there would be room for the moon 240,000 miles away, and for another satellite 190,000 miles beyond her. The mass of the sun, that is, the quantity of matter contained in it, is nearly 330,000 times as great as that of the earth. This mass is about 750 times as great as the combined masses of all the planets and satellites of the solar system; it is two octillions of tons. The attractive pull of this tremendous mass upon the earth, at a distance of nearly 93,000,000 miles, again transcends all conception. It is thirty-six quadrillions of tons;" in figures, 36 followed by 17 ciphers. If gravitation were to cease, and steel wires were used to hold the earth in her orbit, each wire being as large as the heaviest telegraph wire (No. 4), it would require nine to each square inch of the earth's surface, and the whole sunward hemisphere of our globe would have to be covered as thickly as blades of grass upon a lawn. A man who on earth would weigh 250 pounds, would at the sun weigh nearly two tons, and be unable to stir. A planet as far away as the nearest fixed star, which is more than 200,000 times more remote than the sun from the earth, if not disturbed by any other attractions, would still be governed in its motion by the sun, though, if moving in a circle, nearly 90,000,000 years would be required for a single revolution. If the motion seems slow, it is because the distance is so vast; but the planet would still be so powerfully held in its orbit that it could only free itself from solar attraction by darting away with a velocity of more than 300 feet per second.

To the strong eye which can bear its brilliance without flinching, the sun appears as a round white disk, little more than half a degree in diameter. The surface looks uniform, except a slight darkening at the edge, and sometimes black specks upon the bright disk. But when a suitable telescope is applied to the sun, new features arrest attention. At first it is less impressive than the moon, with its mountain ranges, craters, and shadows. But details soon come out, which show that the solar surface is far from uniform. Minute grains of intense brilliance and irregular form appear, arranged in streaks and groups, and which seem to be floating in a darker medium. With a low power the effect is said to resemble that of rough drawing paper, or of curdled milk seen from a little distance. But in favorable times, when higher telescopic power can be used, the grains or "nodules" appear as irregularly rounded masses, measuring some hundreds of miles each way, sprinkled upon a less brilliant background, and looking, as Prof. Langley says, like snowflakes scattered over a grayish cloth. Under the sharpest scrutiny, these grains are sometimes resolved into granules, or luminous dots, not more than 100 miles or so in diameter. Langley estimates that these granules constitute perhaps about one-fifth of the surface of the sun, while they emit at least three-quarters of the light. There has, in former years, been much discrepancy in the views regarding these objects. Nasmyth compared them to "willow leaves," while Secchi named them "rice grains." Some have discerned long, narrow, blunt-ended filaments like bits of straw lying roughly parallel to each other, so that the structure has been called a "thatch straw" formation. Young suggests that the grains are the upper ends of long filaments of luminous cloud, which, over most of the sun's surface, stand nearly vertical. He hints that the cloud masses over the more quiet portions of the solar surface may be, as they seem, nearly globular, though drawn out near the sun's spots into filamentary forms by currents in the solar atmosphere.

Under telescopic observation it is seen that the light falls off very rapidly near the edges of the disk, and here are best observed those remarkable objects called "faculæ," literally meaning "a little torch." These are irregular streaks or patches of greater brightness than the general surface, and resembling flecks of foam below a waterfall. They are often from 5,000 to 20,000 miles long, and cover areas immensely larger than our terrestrial continents. It is represented that in structure these faculæ are elevated regions of the solar surface, ridges and crests of luminous matter, which rise above the general level, and protrude through the denser portions of the solar atmosphere, just as do our terrestrial mountains, although they cannot be seen at all if they are not at least forty-five times as high as any Himalayan. These mountains of light are found to some extent over the whole surface of the sun, though only sparingly in the polar regions. They generally change form and place but slowly, and persist apparently unaltered for several days. Yet it will not do at all to conceive of them as mountains, which involve the idea of stability; the solar surface is a stupendous mass of rolling and tossing flame, in which movements at the rate of 1,000 miles an hour are the rule rather than the exception.

Sun spots early attracted the attention of observers. Many of them are recorded by the Chinese, and in the year 807 A. D. a large spot was visible in Europe for some eight days, which was supposed to be the planet Mercury. But there was great reluctance to admit that the orb of day could be imperfect or that "the eye of the universe could suffer from ophthalmia." But the first rude telescope settled the matter, and sun spots were recognized by various observers as early as 1610-11. But it is only within the last thirty years that these objects have been assiduously and systematically studied. A sun spot generally consists of two portions—a very dark, irregular central portion called the umbra, and which is surrounded by a shade or fringe less dark known as the penumbra and chiefly made up of filaments directed radially inward. It is as if the umbra were a hole and the penumbral filaments overhung and partly shaded it from our view, like bushes at the mouth of a cavern. The details of the spots are continually changing; the bright granules at the tips of the penumbral filaments seem to sink and dissolve, while fresh portions break off to replace them, as if there was a continual indraught of luminous matter over the whole extent of the penumbra. Sun spots are often short-lived objects, seen but once, yet the average life of a sun spot may be taken as two or three months, while the longest lived yet recorded lasted eighteen months. Sometimes one disappears, and is soon replaced by another at the same point. They generally, however, occur in groups; and often a very large spot is accompanied by a train of small ones. The special history of remarkable sun spots has been frequently made out, but it is not safe to generalize from any one set of observations. Almost every one has its own peculiarities, departing in some respect or other from the usual course of things. Spots of unusual magnitude and activity seem often to have no quiet middle life. There is no time in their history when they are not doing something that is surprising, and more or less unprecedented. Their dimensions are sometimes enormous. Many groups have been observed covering areas of more than 100,000 miles square, and single spots have been known to measure 40,000 or 50,000 miles in diameter, the central umbra alone being 25,000 or 30,000 miles across. To be seen by a keen naked eye, a spot would have to measure 23,000 or 24,000 miles. The largest yet recorded was observed in 1858. It had a breadth of more than 143,000 miles, or eighteen times the diameter of the earth, and covered about one-thirty-sixth of the whole surface of the sun. Sun spots travel across the solar surface, being carried around by the rotation of the sun, which takes place once in twenty-five days. They mostly lie between 10 and 35 degrees of latitude on each side of the sun's equator. On the equator itself they are comparatively rare, and there are still fewer beyond the latitude of 35°. The cause of this distribution is not known. Sun spots are not uniform from year to year, but vary in number and intensity, and it has been proved that this variation is periodic. This discovery is due to Schwabe of Dessau, who traced three complete oscillations from maximum frequency through minimum, back to maximum again. He assigned ten years as the sun-spot period, although Wolf has shown that the period is more nearly eleven years. It has been also found that the earth's magnetism fluctuates in intensity, running through a period that is now proved to be coincident with the sun-spot period. It is, moreover, shown that the connection is causal, solar cyclones being accompanied by terrestrial magnetic storms, indicated by extraordinary agitations of the magnetic needle. This evidence of the control of sun spots over earthly phenomena naturally raises the question as to the extent of this influence. May not other phenomena be also influenced by the spot variations? Prof. Young remarks, as to the effect of sun spots upon terrestrial temperature: "No conclusion seems possible at present. The spots themselves, as Henry, Secchi, Langley, and others have shown, certainly radiate to us less heat than the general surface of the sun. According to the elaborate determinations of Langley, the umbra of a spot emits about fifty-four per cent. and the penumbra about eighty per cent. as much heat as a corresponding area of the photosphere. The direct effect of sun spots is, therefore, to make the earth cooler. As the total area covered by spots, even at the time of maximum, never exceeds 1-500 of the whole surface of the sun, it follows that directly they may diminish our heat supply by about 1-1000 of the whole. Whether this effect would be sensible or not is a question not easily answered." We have no space here to state the probabilities and speculations as to the nature and causes of sun spots. They are supposed to be depressions or openings, breaks in the surface of the sun, perhaps in some way connected with the activities in its interior depths.

As has been said, our knowledge of the chemical constituents of the sun is recent, and is due to researches with the spectroscope. The study of the properties of the solar spectrum began with Newton. Fraunhofer found that the spectrum was crossed by a great number of fine dark lines, which were consequently known as Fraunhofer's lines. But it was only recently discovered that these spectral effects have an important chemical significance. The fundamental principle of spectroscopy is that when a body is heated until it becomes luminous, or emits light, the spectrum formed by that light is peculiar. Every chemical element has therefore a characteristic spectrum by which it is known; and no matter how far away it is, the prism that decomposes its ray gives the means of identifying it. The knowledge gained, besides, goes a good deal further than this. There are bright lines and dark lines, and these change from one condition to the other, and in doing so give a clue to the physical condition as well as the chemical identity of the element, so that it may be known whether it is solid, liquid, or gaseous, and how it is related to other and accompanying elements. The lines formed by an incandescent gas are also altered by its state of pressure. More wonderful still, the motions of the chemical source of light can also be determined by the spectrum: the lines being displaced one way if the body is rapidly approaching the observer, and displaced the opposite way if the body is rapidly receding from him. Again, violent commotions among the elements are revealed by distortions of their lines, so that great explosions, hurricanes, and cyclones in the sun are reported to the observer as he watches the changes of the light in his spectroscope. Nor is there the slightest doubt about the certainty of the results. The evidence cannot for a moment be resisted. The spectroscopist finds, for example, that iron heated to the vaporous condition gives a great number of lines of unequal intensities, distributed in unequal groups through a spectral field; and if he places the spectrum of the sun alongside it, the same lines with the same distribution are disclosed, so that they become continuous with each other. By observations of this kind, Kirchoff in 1860 proved that the solar atmosphere contains sodium, iron, calcium, magnesium, nickel, barium, copper, and zinc, though the last two were doubtful at that time. Since then, the list has been much extended, and now includes titanium, cobalt, chromium, hydrogen, palladium, vanadium, molybdenum, strontium, lead, uranium, aluminium, cereum, cadmium, and, probably, oxygen. In addition to these elements, there is a certain degree of probability that indium, lithium, rubidium, iridium, caesium, bismuth, tin, silver, glucinum, lanthanum, yttrium, and carbon are also present in the solar atmosphere; one or more lines of their spectra having been found by Mr. Lockyer to coincide with dark lines in the solar spectrum. There are only doubtful indications of sulphur and no trace of chlorine, bromine, iodine, and silicon. But it is possible that these elements are compound, and exist in a state of dissociation in the solar heat which is far intenser than any temperature we know upon earth. At least two additional elements, as yet unidentified with any terrestrial substance, are recognized by their lines as existing in the solar atmosphere; one of them an unknown element which Prof. Young discovered to be most conspicuous in the corona, and the other a hypothetical element which has received the name of helium. There may, it is probable, be others also, for we cannot suppose that this inquiry is exhausted. But it is an enormous step in the progress of science to have established the fact that the chief constituents of the sun are the same as those that compose the earth, subject here to familiar experimental investigation.

The visible luminous surface of the sun is called the photosphere. The outer surface of this photosphere is pretty sharply defined, although very irregular, rising at points into faculæ, and sinking at others into the dark spots. As to its constitution, the photosphere is now regarded as a vast shell or sheet of self-luminous clouds, formed by the cooling and condensation of the condensable vapors where exposed to the cold of outer space. The clouds of the photosphere are supposed to be like the clouds of our own atmosphere, except that, while ours are condensed watery vapor, the incandescent photospheric masses are condensed metallic vapors precipitated from the solar atmosphere in which they float, and which is the flame of a burning fiery furnace raging with a fury and an intensity beyond all human conception. The depth or thickness of the photospheric shell or layer is quite unknown: nor is it certain whether it is separated from the inner core of the solar body by a definite surface, or whether, on the other hand, there is no boundary between them.

What is below the photosphere—the nucleus or chief body of the sun composing more than nine-tenths of its whole mass—is a matter only of conjecture. It is now generally believed to be gaseous, and the most powerful reason for this opinion is the low specific gravity of the solar mass. The sun is about one and a quarter times heavier than an equal bulk of water, while the earth is five and a half times heavier than water; that is, the earth is considerably more than four times as dense as the sun. We know that metallic vapors abound in the solar atmosphere; but if these metals existed in the solid or liquid form to any great extent, the solar density would be correspondingly increased. And since the temperature, at the surface even, where there is free radiation and exposure to the cold of space, is so high as to keep these bodies in the state of vapor, it is not likely that, at greater depths, it is low enough to permit their liquefaction or solidification. It is well known that the elder Herschel contended that the sun is not only solid but habitable, there being a cool, sheltering layer of clouds beneath the photosphere; and, more recently, Kirchoff and Zöllner have maintained that the luminous surface is either liquid or solid. They urge the difficulties of a gaseous sphere with so high a density as that of the sun. But if we assume that the temperature rises rapidly enough from the surface downward through the solar globe, the whole difficulty as to the density of such a gaseous sphere vanishes. It is true that, on this view, the central temperature must be tremendous, even in comparison with that of the photosphere. But why not? All the facts and probabilities indicate that the intensity of the sun's internal heat must as much exceed that of the photosphere as this surpasses the mere animal warmth of a living body. But while, on the whole, it thus seems probable that the sun's core is gaseous, nothing could be remoter from the truth than to imagine that a mass of gas, under such conditions of temperature and pressure, would resemble our air in its obvious characteristics. It would be denser than water; and since, as Maxwell and others have shown, the viscosity of a gas increases fast with rising temperature, it is probable that it would resist motion something like a mass of pitch or putty. But the elements could not sink into the liquid or solid form except by the reduction of temperature. This subject is very ably and elaborately discussed by Prof. Young.

But while the great mass of the sun is included within the photosphere, yet the larger portion of its volume lies without, forming an atmosphere whose diameter is at least double and its bulk sevenfold that of the central globe. This atmosphere of the sun has an outline of extreme irregularity and variableness. The uniform aspect of the solar disk is an astonishing illusion. There is a stupendous raggedness in the fiery solar appendages, which the term mountainous, in its most exaggerated application, is far too tame to express. At the base of this solar atmosphere, and in contact with the photosphere, is what resembles a vast sheet of scarlet fire. The appearance is as if countless jets of heated gas were issuing through vents over the whole surface, thus clothing it with flame, which heaves and tosses like the blaze of a mighty conflagration. This is the chromosphere, and the ascending masses of incandescent gas are known as the solar "prominences." The chromosphere is a revelation of the spectroscope. Under ordinary circumstances the prominences are invisible, for the same reason as the stars in the daytime; they are hidden by the intense light reflected from the particles of our own atmosphere. Yet by the spectroscope they may be observed in the daytime, and their motions and magnitudes determined. The number of prominences of considerable magnitude (exceeding 10,000 miles in height) visible at any one time on the surface of the sun is never very great, rarely reaching 25 or 30; but their number varies with the number of sun spots, and the two phenomena are generally connected, although their relations are much more close with the faculæ. The chromospheric layer has an average depth of five or six thousand miles, but its elevations are enormously greater than this height. Of 2,767 prominences whose altitudes are recorded, 1,964 rose to 18,000 miles, 751 to 28,000 miles, and several exceeded 84,000 miles. A height of 100,000 miles is not common, but Prof. Young states that he has seen three or four which exceeded 150,000 miles. Secchi describes one 300,000 miles high, and on Oct. 7, 1880, Young observed one which measured 13° of an arc, or 350,000 miles in height. Their forms and structures differ as widely as their magnitude. Some are quiescent, appearing to lie upon the limb of the sun like a bank of clouds in the horizon; and these are comparatively permanent, remaining often for hours and days without much change. Sometimes they float free from the chromosphere; sometimes they appear connected with it by slender columns; and again the whole under surface seems to be fringed with downhanging filaments. Eruptive prominences are of a different aspect and order. Their form and appearance change with great rapidity, a quarter of an hour being often sufficient to transform beyond recognition a mass of these flames 50,000 miles high. Their forms are greatly diverse. Sometimes they have the common aspect of flames, then of pointed divergent rays; "sometimes like sheaves of grain; sometimes like whirling waterspouts capped with a great cloud. Occasionally they present most exactly the appearance of jets of liquid fire rising and falling in graceful parabolas; frequently they carry on their edges spirals like the volutes of an Ionic column." The velocity of their motion often exceeds 100 miles a second, and sometimes, though very rarely, reaches 200 miles. The eruptive gas of these prominences is chiefly hydrogen, and some conception of the terrific force of solar explosions may be inferred from the fact that clouds of hydrogen have been seen thrown to a height of more than 200,000 miles with a velocity which must have exceeded 200 miles a second, and was probably much higher.

Far beyond the region of prominences extends that more etherealized portion of the solar atmosphere known as the corona, or the glory which surrounds the darkened sun during an eclipse. In texture and tenuity it much resembles the tails of comets. This vast irregular aureole of light is the most striking feature in an eclipse. When the solar disk becomes of inky blackness as the moon cuts off its rays, there stream out from all sides radiant filaments, beams, and sheets of pearly light which reach to a distance sometimes of several degrees from the solar surface. The portion nearest the sun is of a dazzling brightness, though less brilliant than the prominences which blaze through it. This inner corona has a pretty uniform height, forming a ring three or four minutes of an arc in width. Beyond this, the halo becomes stellate and irregular, rifted with blackness, and with vast curved streamers and immense bars of light fading away into the darkness. The irregular fantastic forms of the corona that are never visible but for a few moments, are hard to delineate and still more difficult to explain. Hydrogen and other elements are proved by the spectroscope to exist in the corona, showing its continuity with the inferior portions of the solar atmosphere. But while the corona is in great part composed of glowing gas, there is reason to think that it contains also a considerable quantity of matter in such a state as to reflect the sunlight, probably some kind of meteoric dust or fog.

In considering the quantity and intensity of the light emitted by the sun, we are again lost in the bewildering magnitude of numbers. The amount can be measured and proved and stated in familiar terms, but the result cannot be mentally grasped. Though the source of illumination is 93,000,000 miles away, its light would quickly disorganize and destroy the eye exposed to it. Sunlight is the intensest radiance at present known. It so far surpasses the brightness of the calcium light, and even the most powerful electric arc, that if either of these lights is interposed between the eye and the surface of the sun it appears like a black spot upon the disk. An ordinary gas burner consuming five feet of gas hourly gives as much light as sixteen standard candles, and the total light of the sun is computed to be about equivalent to four hundred billion billion of such gas jets. The intensity of the light at the solar surface is estimated to be 190,000 times greater than the average brightness of the candle flame. It is 146 times more brilliant than the calcium light, and probably about four times as intense as the electric light. Prof. Langley compared the brightness of sunlight with the blinding brilliancy of the molten metal in a Bessemer "converter." But the dazzling stream of melted iron was deep brown, compared with the solar radiation, and presented a contrast like that of dark coffee poured into a white cup. No allowance being made by the absorption of the sun's rays by passing through the smoky air of Pittsburgh, they came out 5,300 times brighter than the dazzling radiance of the incandescent metal. But the solar light is much feebler at the sun's border than at the central region of the disk, which is accounted for by the absorption of a portion of the rays by the solar atmosphere. La Place maintained that this absorption of light by the sun's atmosphere amounts to eleven-twelfths of the whole, and Secchi agrees with him. But other authorities make it less, and say that the sun without its atmosphere would be about four times as bright as we now see it.

All the sun's rays are lines of force manifested and measured by material changes. They are all believed to be of the nature of waves or pulses which expend themselves in the production of motions. The luminous rays to which we have just referred impress the nervous matter of the eye and thus give rise to vision. The actinic rays produce chemical decompositions, and the thermal rays give rise to expansion, but all the waves of solar radiation are carriers of energy, and when intercepted do work. The measurement of solar heat is more satisfactory than that of solar light, as thermometers are more accurate, than photometers with candle power units.

But there is a preliminary difficulty from the absorption of heat by the earth's atmosphere. A considerable part of it is thus intercepted and cannot be measured. Yet this loss has been proximately determined. "Speaking loosely, it may be estimated that at the sea level in fair weather, neither excessively moist nor dry, about 30 per cent. of the solar radiation is absorbed when the sun is at the zenith, and at least 75 per cent. at the horizon. Of the rays striking the upper surface of our atmosphere, between 45 and 50 per cent., therefore, are generally intercepted in the air, even when there are no clouds." Of course, this heat is not lost to the earth; but when we come to measure the actual amount received upon a square foot of the earth's surface, it must be remembered that it is but little more than half of that which has been emitted by the sun.

The amount of solar heat actually received upon given areas of the earth's surface has been determined in various ways, which need not be here described. If we express the result in terms of power, and take the whole surface of the earth, the average energy received from the sun on every thirty square feet of the earth's surface is equal to one continuous horse power. It is assumed that the sun radiates equally in all directions, so that if he were surrounded by a sphere as large as the earth's orbit, or 186,000,000 miles in diameter, his radiations would give a dynamic effect of a perpetual horse power upon each thirty square feet of this enormous surface. Of the total solar radiations, the earth receives only a fraction of inconceivable minuteness, but one twenty-two-hundred-millionth of the whole. Yet this almost infinitesimal fraction of solar power is the great capital of terrestrial energy: wind power, water power, electric power, steam power, and the power of all living organisms.

Herschel has given the great result in terms of melting ice. A shell of ice an inch thick and 186,000,000 miles in diameter, surrounding the sun, would be melted in two hours and thirteen minutes. A shell of ice enclosing the sun at his surface, a mile in thickness, would be melted in the same time. Herschel continues, that if a cylinder of ice forty-five miles in diameter were darted into the sun with the velocity of light, the sun's heat, if concentrated upon it, would melt it as fast as it came; or, in other words, if a solid column of ice two and a quarter miles in diameter and 93,000,000 miles long, that should span the abyss from the earth to the sun, could be acted upon by the total solar heat, it would be melted in a single second, and in seven seconds more it would be dissipated in vapor. It has again been computed that the heat streaming from the sun into space would be sufficient to boil 700,000,000,000 cubic miles of ice water each hour. The burning glass by which the solar rays are concentrated produces an effect which is equivalent to moving the object in its focus a certain distance toward the sun, depending upon the size and power of the glass. "The most powerful lens yet constructed thus virtually transports an object at its focus to within about 250,000 miles of the sun's surface, and in this focus the most refractory substances are either instantly melted or dissipated in vapor. There can be no doubt that if the sun were to come as near us as the moon the solid earth would melt like wax." As to the sun's temperature, there is great discrepancy in the calculation. The intensest heat that can be produced upon earth is perhaps 4,000° F., but the sun's temperature has been estimated at from 10,000° F. all the way up to four or five million degrees. Langley, who has investigated this point with great care, found that the heat radiation of the solar surface is more than eighty-seven times as intense as that from the molten iron in the Bessemer converter.

As to the causes of this heat, and how it is sustained, and how long it will probably last, and many other interesting questions which we have had no room to touch, the reader is referred to Prof. Young's charming book, the most instructive and impressive volume ever written upon this subject.

Two Books About Scandinavia.

There has been lately somewhat of a glut of books purporting to record the hastily caught impressions of travellers not particularly qualified to discourse on Norway and Sweden. If intelligent persons able to speak fluently the languages of Scandinavia would sojourn in some of its chief cities long enough to become intimately acquainted with the manners, habits, and points of view of the inhabitants, their report would be interesting. There is room also for a volume in which localities associated with romantic or important events should be described by a writer thoroughly saturated with Scandinavian history; but here again a knowledge of Norse and Swedish, if not of Danish also, would be indispensable. As for the ordinary tourists who suppose themselves equipped for bookmaking because they have seen Drontheim and Upsala, have gazed upon the midnight sun, have perhaps been driven behind a reindeer, and picked up half a dozen phrases from much-enduring innkeepers, there is really no longer any call for their random jottings. These remarks are suggested by a volume entitled the *Story of a Scandinavian Summer*, by KATHERINE E. TYLER (Putnams). They do not apply, for reasons to be mentioned presently, to another book just issued by the same publishers, and called *Norse, Lapp, and Finn*, by FRANK VINCENT, Jr.

The author of "A Scandinavian Summer" landed at Christiania, journeyed by land to Drontheim, and went then by steamer to Tromsoe, which was as near as she got to the midnight sun. On her return she went to Christiania, to Stockholm by rail, and made an excursion to Upsala. On the strength of this experience she proceeded to make a book, and let us say at once that her performance is no worse, and rather better as regards vivacity of style, than the score or two of works which, unhappily, already occupy the not very extensive field. The writer seems to have read carefully such popular summaries of the Scandinavian annals as exist in English, and she has transferred to her pages a good deal of the erudition to be met with in guide books. Altogether her chapters read like letters, which, no doubt, may have been listened to with interest and admiration in a family circle whose members knew even less of the subject than the author. But really this sort of journal, in which a keen-eyed, quick-witted, but in no wise specially equipped person, notes what she happens to see from a carriage window, or the deck of a steamer, or what she chances to hear from a travelling acquaintance or a companion at dinner, has gone entirely out of date. What we want is new facts, and these are only to be procured by travellers, or explorers, who know beforehand just where to look for them, and can distinguish them when they see them. The old commonplace observations, which had some zest and value when Norway and Sweden were comparatively unvisited, are now quite savorless, and it requires a literary artist like Signor De Amicis to concoct a piquant and attractive dish out of such materials.

The first point which distinguishes Mr. Vincent's book from the last named is that he refrains from inflicting on us any of the second-hand learning to be gleaned so easily from popular histories and guide books. He tells us simply what he saw (and he saw a great deal more than the lively author of "A Scandinavian Summer"), and what he learned by personal inquiry (and he knew much better what to ask about, and where to put his questions.) He spent, for instance, some time on the threshold of his journey on the less frequented coasts and the interior of the Island of Zealand. Not far from Roeskilde, which was the capital of Denmark, down to the middle of the fifteenth century, but which probably not one American tourist in a hundred thousand ever visits, he was shown a dolmen or burial grotto, 22 feet long, 6 feet high, and 18 feet wide, and which, when first opened, contained a number of skeletons and a quantity of arms. North of Roeskilde too, and not far away, is one of the largest kitchen mittens in existence, containing relics of the race which dwelt here long before the advent of the Aryan type in Europe. The whole neighboring district is rich, it seems, in dolmens and kitchen mittens, as well as in barrows, tumuli, and raised stones, bearing Runic inscriptions; the latter memorials, of course, belonging to a much later period. Such monuments could not fail to engage the attention of an intelligent traveller, aware of Sir John Lubbock's opinion that the prehistoric, pre-Aryan age of Scandinavia must have been its most splendid era. Mr. Vincent was not content to stop at Tromsoe, but went on to the North Cape, where, however, as Bayard Taylor had preceded him, he does not trouble us at much length with his impressions of the midnight sun and Arctic scenery. Mr. Taylor, however, knew but little about Lapland, and three of the most valuable chapters of Mr. Vincent's book give us the results of his personal study of the Lapps in their own homes. He tells us that the extremely low stature attributed to the Lapps by the first English voyagers proves, on an extended acquaintance with the race, not to be at all exaggerated. They average in height only four feet and a half, and a Lapp five feet tall would be regarded as a prodigy. Their type seems to indicate an admixture of Mongolian and Caucasian blood, but Mr. Vincent agrees with other authorities in tracing more of the Mongol characteristics in their physiognomy. In color, he says, they are yellowish brown, and they have large heads with broad and low foreheads, light black eyes, flat short noses, broad mouths, high cheek bones, scanty beards, and long, stiff black hair. Their voices are not euphonious, being low and squeaky. The author adds that they possess great muscular power, and are extremely agile. On the ethnological problem touching the origin of this strange race, Mr. Vincent does not assume to throw any light; but as regards their final migration, he infers, apparently from their own traditions and their distribution in their present habitat, that they were the original inhabitants of Finland, and were slowly crowded northward by the Finns proper. The Lapp race is said to number at the present day no more than 17,000 souls. Originally all the Laplanders were nomadic; but the difficulty of finding sufficient food has divided them into two groups, the roving and the settled, or the mountain and the seacoast Lapps. So strong, however, is the Norwegian prejudice against them that not even those who live by fishing are allowed to remain permanently in any of the Norse towns. The Lapps, it seems, never cook either fish or blubber, but eat their flesh all raw, a fact of which the sixteenth century travellers made mention. Not only the men, but the women and the young girls, are perpetually drunk so long as any of the vile corn brandy, which they distil themselves, is procurable. The exposed and grossly intemperate life of these people does not seem to diminish their vigor or their longevity. A Lapp will get drunk, fall asleep in a snow drift, and awake in the morning as vigorous and lively as he was the day before. Often, in midwinter, a Lapp woman, wandering with her people in the snow, in search of reindeer moss, will give birth to a child, and after a brief repose will continue the journey without any evil consequences.

Among the features of prehistoric society preserved among the Lapps may be noted their regulations regarding marriage. Polygamy is practised, and marriageable girls are still frequently sold by their parents, the price received being considered as a repayment of the expenses incurred in bringing up a daughter, and as a compensation to the father for the loss of her services. When we bear in mind the existence of polygamy, it seems a curious anomaly that the Lapps never permit divorce. In some of the Lapp communities polyandry is a recognized form of the connubial relation. Mr. Vincent tells us that the Lapp language has eleven cases, and three numbers, but no gender. We observe that in the brief glossary furnished by him all the words are dissyllabic. We are told that there are five words for snow, and seven for a mountain, but that honesty, virtue, and conscience must be expressed by a paraphrase. The Lapps possess no manuscripts, and of course no printed books of their own, but the Bibles and some religious publications have been issued in their tongue by the Norwegian Government. They have, however, many traditional histories, myths, and songs. A good many of the Lapps are baptized, it seems, when young, but the majority are still addicted to polytheism. Among their deities are several of the old Teutonic divinities, but there also seems to be among them traces of Druidical institutions.

In a chapter on the reindeer, Mr. Vincent gives his personal observations of this useful animal, which has appropriately been termed the camel of the North. He tells us that most of them are of a dark slate color, though a few are brown, and some quite white. They are hardly three feet in height, and perhaps four or five in length. The great size of their antlers presents a striking contrast with their comparatively small bodies. The antlers of a buck are often as much as four feet in length, with branches called brow antlers projecting far forward from their bases, and with spurs spread out fanwise at their upper ends. Small as he is, a reindeer is able to carry for long distances about 130 pounds, or he can draw over the glazed snow, when harnessed to a sledge, 250 pounds. Its hoof is as admirably adapted for travel in the snow and morasses of the frigid zone as the hoof of the camel is for the sand and hillocks of the torrid belt. In Lapland a reindeer will readily travel ten miles an hour all day, and there is an instance on record of twenty miles having been made in a single hour as a test of speed. In 1699 a reindeer drew an officer, with important despatches, 800 miles in two days, or an average of 16⅔ miles an hour. This astounding feat ended in the death of the deer, whose portrait, we are told, is still preserved in the summer palace of Drottningholm, near Stockholm. All that we derive from the horse, the ox and the sheep, this wonderful little animal furnishes the Laplander. Much of the meat, in its fresh state, is cooked and used as food but some after being cut into thin slices is dried or smoked, and then takes the place of bread. The pennican which the Arctic explorers use is made from reindeer flesh. The milk, which is excessively rich, is drunk fresh, or made into a rank and unctuous cheese and a kind of butter that tastes like suet. From the cheese an oil is made which is the sovereign specific for frozen flesh. The whey is used for drink, and is sometimes converted into a fermented beverage analogous to koumiss. The skins of the deer furnish the winter tents of the Laplanders, their blankets, and articles of clothing, and, in short, serve almost every purpose to which we apply cloth or leather. The women prepare from the tendons, by rolling them with their hands upon their cheeks, a thread which surpasses all others in strength and durability. The antlers supply the requisites of their household and culinary apparatus. The reindeer, without which the Lapps could not exist, are a very precarious possession, owing to the difficulty of procuring their subsistence during winter. The moss, or lichen, on which they feed is often buried beneath as much as six weeks of snow, which the deer themselves have to remove with their feet and follow their nose. Mr. Vincent tells us that the reindeer moss is capable of being used for human food; its nutritive properties are derived from the starch which it contains, and the taste is not unpleasant when the moss is boiled with reindeer milk.

Mr. Vincent spent some time among the copper and iron mines of Dalecarlia, the cradle of Sweden's civil and religious liberty. The author dwells on the simplicity of manners, dress, and mode of living in this province, and points out that the inhabitants speak a language which is said to resemble the Gaelic. The fact indicates a profound difference of race between the natives of this region and those of Gothland, at the southern end of the peninsula, and perhaps furnishes the key to Sweden's early and mediæval history. Mr. Vincent observed that, notwithstanding the strict supervision of the Government, the forests in the neighborhood of the mines are nearly exhausted. Their disappearance bodes ill for the future of the mining industry, for, as is well known, the superiority of the Swedish iron does not arise solely from the purity of the ore, but partly in consequence of its being smelted with charcoal.

The visit which our traveller made to Finland has enabled him to enrich his volume with some information about that too seldom visited country. It appears that after 1883 Finnish is to become the official language; this will bring about a species of revolution in social life and literature, for until recently Swedish has been spoken among the upper classes, and most books have been printed in that language. Yet as early as 1548 the New Testament and Psalter were published in the Finnish tongue. Weekly Finlandish newspapers circulate among the peasantry, and of late an attempt has been made to translate Schiller, and even Shakespeare, into the native language. Mr. Vincent gives some extracts from Kalevala, the great Finlandish epic, which was first collected in printed form in 1835, but which had been handed down on the lips of the peasantry from immemorial time. We are reminded that Max Müller has recognized in the Kalevala merits not dissimilar to those of the Iliad and the Niebelunge, and is disposed to rank it as the fifth national epic of the world.

A SCHOOLMISTRESS'S OBSERVATIONS.

Odd Glimpses of Human Nature Caught in a Virginia Free School.

TO THE EDITOR OF THE SUN—*Sir:* I think a bit of my experience in school teaching in Virginia is worth telling. Fancy a log house daubed with the reddest of red mud, with royal oak trees shaking hands over its low roof. That is my schoolhouse. Fancy a middle-aged, middle-sized, timorous woman, installed for the first time in the chair of authority. That is I. Before me, on long, backless benches, sit my scholars, gazing with eyes like gimlets; one funny boy, two stupids, three curly-headed girls, four with red hair, all the rest being composed of sandy hair, freckles, and snaggled teeth, with blue eyes like glass marbles, as like as a handful of blackeye peas.

It is the fashion, in my school, for notes to come to me from the parents written on the children's slates.

> Sary Ann is not by no means to be let sit beside of Uberia Tuck. The tambilies not settin' horses at this present.
>
> I would like Willy Anna to learn the pianner. I hear you sack the chunes very clever.
>
> I request of you to hold in my son Adoniram. He is a torrid child and will get ahead of his helth unless held in.

A boy with a mouth like a catfish says:

"Oh, Miss Simpson! Pa he says he don't want no grammar spread on me, and I am to spell in his old yaller speller; for he ain't got no confidence in them blue spellers."

Having occasion to correct a boy for saying "that ar slate," the same catfish scornfully observes: "Don't it sound jest like a nigger? I always says that thar."

Tommy comes late, but instead of an excuse he beams upon me with eyes like stars. A little muddy dog slinks in, nearly throwing him down, and he draws out of his bag a mangled, draggled squirrel, and holds it up in triumph.

"That's what me and Trot done. He treed him, and I throwed at him, and me and he and him had it thar, tussilin' like wildcats; and I hope you'll 'cept of him, marm."

Oh, but they do smite the English grammar in the face!

"Mary, what is a quadruped?"

"A dangerous weapon used in war."

"No."

"A large, violent bird."

"No."

"Oh, Miss Simpson," from the irrepressible catfish, "I seen one at the circus. Hit's got a tail like a catter—catter—cattermount, and ears like a possum."

The pride of this world and the glory! It freely flourishes in a free school. There is the pride of family, which keeps Sary Ann apart from Miss Tuck. The pride of four ruffles creates an impassable gulf between Miss Charity Stubbs and the one-ruffle girls with a lino piece. There is the pride of spelling and the pride of Johnny's pa owning a pea patch and a mule, over Tom, Dick, and Harry, who own nothing and must "get further."

Oh, the head tossings, and the sniffings, and this one too good to go with that one! *Vanitas vanitatum!* E. M. D.

VIRGINIA, Oct. 8.