THE NEW ASTRONOMY. III.

THE SUN'S ENERGY.

"It is indeed," says good Bishop Berkeley, "an opinion strangely prevailing amongst men that . . . all sensible objects have an existence . . . distinct from their being perceived by the understanding. But . . . some truths there are, so near and obvious to the mind, that a man need only open his eyes to see them. Such I take this important one to be, namely, that all the choir of heaven and furniture of the earth—in a word, all those bodies which compose the mighty frame of the world — have not any subsistence without a mind."

We are not going to take the reader along "the high priori road" of metaphysics, but only to speak of certain accepted conclusions of modern experimental physics, which do not themselves, indeed, justify all of Berkeley's language, but to which these words of the author of "A New Theory of Vision" seem to be a not unfit prelude. When we see a rose-leaf, we see with it what we call a color, and we are apt to think it is in the rose. But the color is in *us*, for it is a sensation which something coming from the sun excites in the eye; so that if the rose-leaf were still there, there would be no color unless there were an eye to receive and a brain to interpret the sensation. Every color that is lovely in the rainbow or the flower, every hue that is vivid in a ribbon or somber in the grave harmonies of some old Persian rug, the metallic luster of the humming-bird or the sober imperial yellow of precious china,—all these have no existence *as* color apart from the seeing eye, and all have their fount and origin in the sun itself.

"Color" and "light," then, are not, properly speaking, external things, but names given to the sensations caused by an uncomprehended something radiated from the sun when this falls on our eyes. If this very same something falls on our face it produces another kind of sensation, which we call "heat," or if it falls on a thermometer it makes it rise; while if it rests long on the face it will produce yet another effect, "chemical action,"— for it will *tan* the cheek, producing a chemical change there; or, it will do the like work more promptly if it meet a photographic plate. If we bear in mind that it is the identically same thing (whatever that is) which produces all these diverse effects, we see, some of us perhaps for the first time, that "color," "light," radiant "heat," "actinism," etc., are only names given to the diverse effects of some thing, not things themselves, so that, for instance, all the splendor of color in the visible world exists only in the eye that sees it. The reader must not suppose that he is here being asked to entertain any metaphysical subtlety. We are considering a fact almost universally accepted within the last few years by physicists, who now generally admit the existence of a something coming from the sun, which is not itself light, heat, or chemical action, but of which these are effects. When we give this unknown thing a name, we call it "radiant energy."

How it crosses the void of space we cannot be properly said to know, but all the phenomena lead us to think it is in the form of motion in some medium—somewhat (to use an imperfect analogy) like the transmission through the air of the vibrations which will cause sound when they reach an ear. This, at any rate, is certain, that there is an action of some sort incessantly going on between us and the sun, which enables us to experience the effects of light and heat. We assume it to be a particular mode of vibration, but whatever it is, it is repeated with incomprehensible rapidity. Experiments recently made by the writer show that the *slowest* heat vibrations which reach us from the sun succeed each other nearly 100,000,000,000,000 times in a single second, while those which make us see have long been known to be more rapid still. These pass outward from the sun in every direction, in ever-widening spheres; and in them, so far as we know, lies the potency of motion and life for the planet upon whose surface they fall.

Did the reader ever consider that next to the mystery of gravitation, which draws all things on the earth's surface down, comes that mystery — not seen to be one because so familiar — of the occult force in the sunbeams which lifts things *up?* The incomprehensible energy of the sunbeam brought the carbon out of the air, put it together in the weed or the plant, and lifted each tree-trunk above the soil. The soil did not lift it, any more than the soil in Broadway lifted the spire of Trinity. Men brought stones there in wagons to build the church, and the sun brought the materials in its own way, and built up alike the slender shaft that sustains the grass blade and the column of the pine. If the tree or the spire fell, it would require a certain amount of work of men or horses or engines to set it up again. So much actual work at least the sun did in the original building; and if we consider the number of trees in the forest, we see that this alone is something great. But besides this, the sun locked up in each tree a store of energy thousands of times greater than that which was spent in merely lifting the trunk from the ground, as we may see by unlocking it again, when we burn the tree under the boiler of an engine; for it will develop a power equal to the lifting of thousands of its kind, if we choose to employ it in this way. This is so true, that the tree may fall, and turn to coal in the soil, and still keep this energy imprisoned in it, — keep it for millions of years, till the black lump under the furnace gives out, in the whirling spindles of the factory or the turning wheel of the steam-boat, the energy gathered in the sunshine of the primeval world.

The most active rays in building up plant-life are said to be the yellow and orange, though nature's fondness for green everywhere is probably justified by some special utility. At any rate, the action of these solar rays is to decompose the products of combustion, to set free the oxygen, and to fix the carbon in the plant. Perhaps these words do not convey a definite meaning to the reader, but it is to be hoped they will, for the statement they imply is wonderful enough. Swift's philosopher at Laputa, who had a project for extracting sunbeams out of cucumbers, was wiser than his author knew; for cucumbers, like other vegetables, are now found to be really in large part put together by sunbeams, and sunbeams, or what is scarcely distinguishable from such, could with our present scientific knowledge be extracted from cucumbers again, only the process would be too expensive to pay. The sunbeam, however, does what our wisest chemistry cannot do: it takes the burned-out ashes and makes them into green wood again; it takes the close and breathed-out air and makes it sweet and fit to breathe, by means of the plant, whose food is the same as our poison. With the aid of sunlight a lily would thrive on the deadly atmosphere of the "black hole of Calcutta"; for this bane to us, we repeat, is vital air to the plant, which breathes it in through all its pores, bringing it into contact with the chlorophyl, its green blood, which is to it what the red blood is to us; doing almost everything, however, by means of the sun ray; for if this be lacking, the oxygen is no longer set free or the carbon retained, and the plant dies. This too brief statement must answer instead of a fuller description of how the sun's energy builds up the vegetable world.

But the ox, the sheep, and the lamb feed on the vegetable, and we in turn on them (and on vegetables too); so that, though we might eat our own meals in darkness and still live, the meals themselves are provided literally at the sun's expense, virtue having gone out of him to furnish each morsel we put in our mouths. But while he thus prepares the material for our own bodies, and while it is plain that without him we could not exist any more than the plant, the processes by which he acts grow more intricate and more obscure in our own higher organism, so that science as yet only half guesses how the sun makes us. But the making is done in some way by the sun, and so almost exclusively is every process of life.

It is not generally understood, I think, how literally true this is of every object in the organic world. In a subsequent illustration we shall see a newspaper being printed by power directly and visibly derived from the sunbeam. But all the power derived from coal, and all the power derived from human muscles, comes originally from the sun, in just as literal a sense; for the paper on which the reader's eye rests was not only made primarily from material grown by the sun, but was stitched together by derived sun-power, and by this, also, each page was printed, so that the amount of this solar radiation expended for printing each number of this magazine could be stated with approximate accuracy in figures. To make even the reader's hand which holds this page, or the eye which sees it, energy again went out from the sun; and in saying this I am to be understood in the plain and common meaning of the words.

Did the reader ever happen to be in a great cotton-mill, where many hundreds of operatives watched many thousands of spindles? Nothing is visible to cause the multiplied movement, the engine being perhaps away in altogether another building. Wandering from room to room, where everything is in motion derived from some unseen source, he may be arrested in his walk by a sudden cessation of the hum and bustle — at once on the floor below, and on that above, and all around him. The simultaneousness of this stoppage at points far apart when the steam is turned off strikes one with a sense of the intimate dependence of every complex process going on upon some remote invisible motor. The cessation is not, however, absolutely instantaneous, for the great fly-wheel, in which a trifling part of the motor power is stored, makes one or two turns more, till the energy in this, also, is exhausted, and all is still. The coal-beds and the forests are to the sun what the fly-wheel is to the engine; all their power comes from him; they retain a little of it in store, but very little by comparison with the original; and were the change we have already spoken of to come over the sun's circulation,—were the solar engine disconnected from us,—we could go on perhaps a short time at the cost of this store, but when this was over it would be over with us, and all would be still here too.

Is there not a special interest for us in that New Astronomy which considers these things, and studies the sun, not only in the heavens as a star, but in its workings here, and so largely in its relations to man?

SINCE, then, we are the children of the sun, and our bodies a product of its rays, as much as the ephemeral insects that its heat hatches from the soil, it is a worthy problem to learn how things earthly depend upon this material ruler of our days. But although we know it does nearly all things done on the earth, and have learned a little of the way it builds up the plant, we know so little of the way it does many other things here that we are still often only able to connect the terrestrial effect with the solar cause by noting what events happen together. We are in this respect in the position of our forefathers, who had not yet learned the science of electricity, but who noted that when a flash of lightning came a clap of thunder followed, and concluded as justly as Franklin or Faraday could have done that there was a physical relation between them. Quite in this way, we who are in a like position with regard to the New Astronomy, which we hope will one day explain to us what is at present mysterious in our connection with the sun, can as yet often only infer that when certain phenomena there are followed or accompanied by others here, all are really connected as products of one cause, however dissimilar they may look, and however little we know what the real connection may be.

There is no more common inquiry than as to the influence of sun-spots on the weather; but as we do not yet know the real nature of the connection, if there be any, we can only try to find out by assembling independent records of sun-spots and of the weather here, and noticing if any changes in the one are accompanied by changes in the other; to see, for instance, if when sun-spots are plenty the weather the world over is rainy or not, or to see if when an unusual disturbance breaks out in a sun-spot any terrestrial disturbance is simultaneously noted.

When we remember how our lives depend on a certain circulation in the sun, of which the spots appear to be special examples, it is of interest not only to study the forms within them, as we have already been doing here, but to ask whether the spots themselves are present as much one year as another. The sun sometimes has numerous spots on it, and sometimes none at all; but it does not seem to have occurred to any one to see whether they had any regular period for coming or going till Schwabe, a magistrate in a little German town, who happened to have a small telescope and a good deal of leisure, began for his own amusement to note their number every day. He commenced in 1826, and with German patience observed daily for forty years. He first found that the spots grew more numerous in 1830, when there was no single day without one; then the number declined very rapidly, till in 1833 they were about gone; then they increased in number again till 1838, then again declined; and so on, till it became evident that sun-spots do not come and go by chance, but run through a cycle of growth and disappearance, on the average about once in every eleven years. While amusing himself with his telescope, an important sequence in nature had thus been added to our knowledge by the obscure Hofrath Schwabe, who indeed compares himself to Saul, going out to seek his father's asses and finding a kingdom. Old records made before Schwabe's time have since been hunted up, so that we have a fairly connected history of the sun's surface for nearly a hundred and fifty years; and the years when spots will be plentiful and rare can now be often predicted from seeing what has been in the past. Thus I may venture to say that the spots, now so frequent, will have probably nearly disappeared in 1888, and will be probably very plentiful in 1894. I do not know at all why this is likely to happen; I only know that it has repeatedly happened at corresponding periods in the past.

"Now," it may be asked, "have these things any connection with weather changes, and is it of any practical advantage to know if they have?"

Would it be, it may be answered, of any practical interest to a merchant in breadstuffs to have private information of a reliable character that crops the world over would be fine in 1888 and fail in 1894? The exclusive possession of such knowledge might plainly bring "wealth beyond the dreams of avarice" to the user; or, to ascend from the lowest ground of personal interest to the higher aims of philanthropy and science, could we predict the harvests, we should be armed with a knowl-

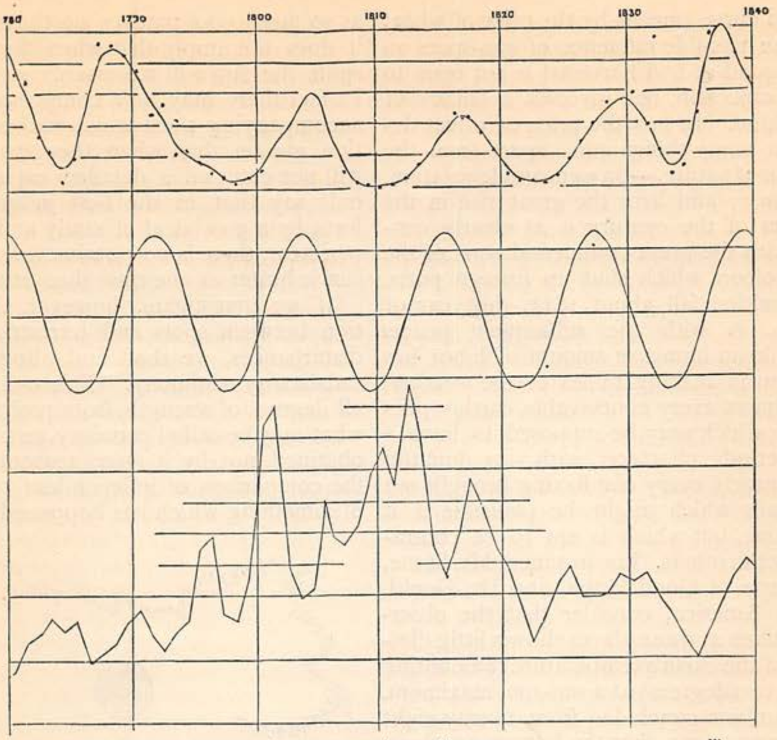

FIG. 1.—SUN-SPOTS AND PRICE OF GRAIN. (FROM "OBSERVATIONS OF SOLAR SPOTS.")

edge that might provide against coming years of famine, and make life distinctly happier and easier to hundreds of millions of toilers on the earth's surface.

"But can we predict?" We certainly cannot till we have, at any rate, first shown that there is a connection between sun-spots and the weather. Since we know nothing of the ultimate causes involved, we can only at present, as I say, collect records of the changes there, and compare them with others of the changes here, to see if there is any significant coincidence. To avoid columns of figures, and yet to enable the reader to judge for himself in some degree of the evidence, I will give the results of some of these records represented graphically by curves, like those which he may perhaps remember to have seen used to show the fluctuations in the value of gold and grain, or of stocks in the stock-market. It is only fair to say that mathematicians used this method long before it was ever heard of by business men, and that the stock-brokers borrowed it from the astronomers, and not the astronomers from them.

In Fig. 1, from Carrington's work, each horizontal space represents ten years of time, and the figures in the upper part represent the fluctuations of the sun-spot curve. In the middle curve, variations in vertical distances correspond to differences in the distance from the sun of the planet Jupiter, the possibility of whose influence on sun-spot periods can thus be examined. In the third and lowest, suggested by Sir William Herschel, the figures at the side are proportional to the price of wheat in the English market, rising when wheat ruled high, falling when it was cheap. In all three curves one-tenth of a horizontal spacing along the top or bottom corresponds to one year; and in this way we have at a glance the condensed result of observations and statistics for sixty years, which otherwise stated would fill volumes. The result is instructive in more ways than one. The variations of Jupiter's distance certainly do present a striking coincidence with the changes in spot frequency, and this may indicate a real connection between the phenomena; but before we decide that it does so, we must remember that the number of cycles of change presented by the possible combination of planetary periods is all but infinite. Thus we might safely undertake, with study enough, to find a curve, depending solely on certain planetary configurations, which yet would represent with quite striking agreement for a time the rise and fall in any given railroad stock, the relative numbers of Democratic and Republican congressmen from year to year, or anything else with which the heavenly bodies have in reality as little to do.

The third curve (meant by the price of wheat to test the possible influence of sun-spots on years of good or bad harvests) is not open to the last objection, but involves a fallacy of another kind. In fact the price of wheat depends on many things quite apart from the operations of nature,—on wars and legislation, for instance; and here the great rise in the first years of the century is as clearly connected with the great continental wars of the first Napoleon, which shut up foreign ports, as the sudden fall about 1815, the year of Waterloo, is with the subsequent peace. Meanwhile an immense amount of labor has been spent in making tables of the weather, and of almost every conceivable earthly phenomenon which may be supposed to have a similar periodic character, with very doubtful success, nearly every one having brought out some result which might be plausible if it stood alone, but which is apt to be contradicted by the others. For instance, Mr. Stone, at the Cape of Good Hope, and Dr. Gould, in South America, consider that the observations taken at those places show a little diminution of the earth's temperature (amounting to one or two degrees) at a sun-spot maximum. Mr. Chambers concludes, from twenty-eight years' observations, that the hottest are those of most sun-spots. So each of these contradicts the other. Then we have Gelinck, who, from a study of numerous observations, concludes that all are wrong together, and that there is really no change in either way.

I might go on citing names with no better result. One observer tabulates observations of terrestrial temperature, or rain-fall, or barometer, or ozone; another, the visitations of Asiatic cholera; while still another (the late Professor Jevons) tabulates commercial crises with the serious attempt to find a connection between the sun-spots and business panics. Of making such cycles there is no end, and much study of them would be a weariness I will not inflict.

Our own conclusion is, that from such investigations of terrestrial changes nothing is yet certainly known with regard to the influence of sun-spots on the weather. There is, however, quite another way, that is, to measure their effect at the origin in the sun itself. The sun-spot is cooler than the rest of the surface, and it might be thought that when there are many the sun would give less heat. As far as the spots themselves are concerned this is so, but in a very small degree. I have been able to ascertain how much this deprivation of heat amounts to, and find it is a real but a most insignificant quantity, rising to about two-thirds of one degree Fahrenheit every eleven years. This, it will be remembered, is the direct effect of the spots considered merely as so many cool patches on the surface, and it does not imply that when there are most spots the sun will necessarily give less heat. In fact there may be a compensating action accompanying them which makes the radiation greater than when they are absent. I will not enter on a detailed explanation, but only say that in the best judgment I can form by a good deal of study and direct experiment, there is no certain evidence that the sun is hotter at one time than at another.

If we investigate, however, the connection between spots and terrestrial magnetic disturbances, we shall find altogether more satisfactory testimony. This evidence is of all degrees of strength, from probability up to what may be called certainty, and it is always obtained, not by *a priori* reasoning, but by the comparison of independent observations of something which has happened on the sun

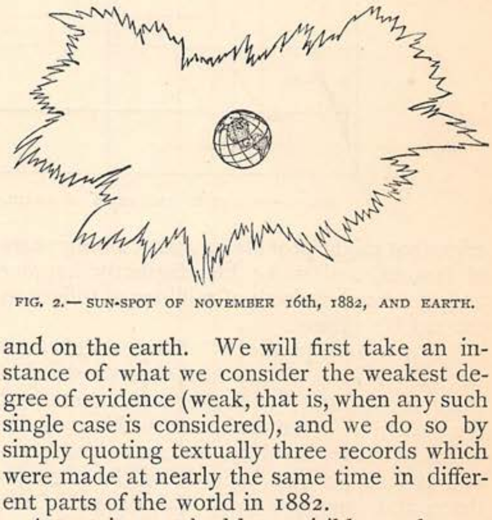

FIG. 2.— SUN-SPOT OF NOVEMBER 16th, 1882, AND EARTH.

and on the earth. We will first take an instance of what we consider the weakest degree of evidence (weak, that is, when any such single case is considered), and we do so by simply quoting textually three records which were made at nearly the same time in different parts of the world in 1882.

A certain spot had been visible on the sun at intervals for some weeks; but when on the 16th of November a glimpse was caught of it after previous days of cloudy weather, the observer, it will be seen, is struck by the great activity going on in it, and, though familiar with such sights, describes this one as "magnificent."

From the daily record at the Allegheny Observatory, November 16th, 1882:

> "Very large spot on the sun; . . . great variety of forms; inrush from S. E. to S. W.; tendency to cyclonic action at several points. The spot is apparently near its period of greatest activity. A magnificent sight."

At the same time a sketch was commenced which was interrupted by the cloudy weather of this and following days. The outline of the main spot only is here given (Fig. 2). Its area, as measured at Allegheny, was 2,200,000,000

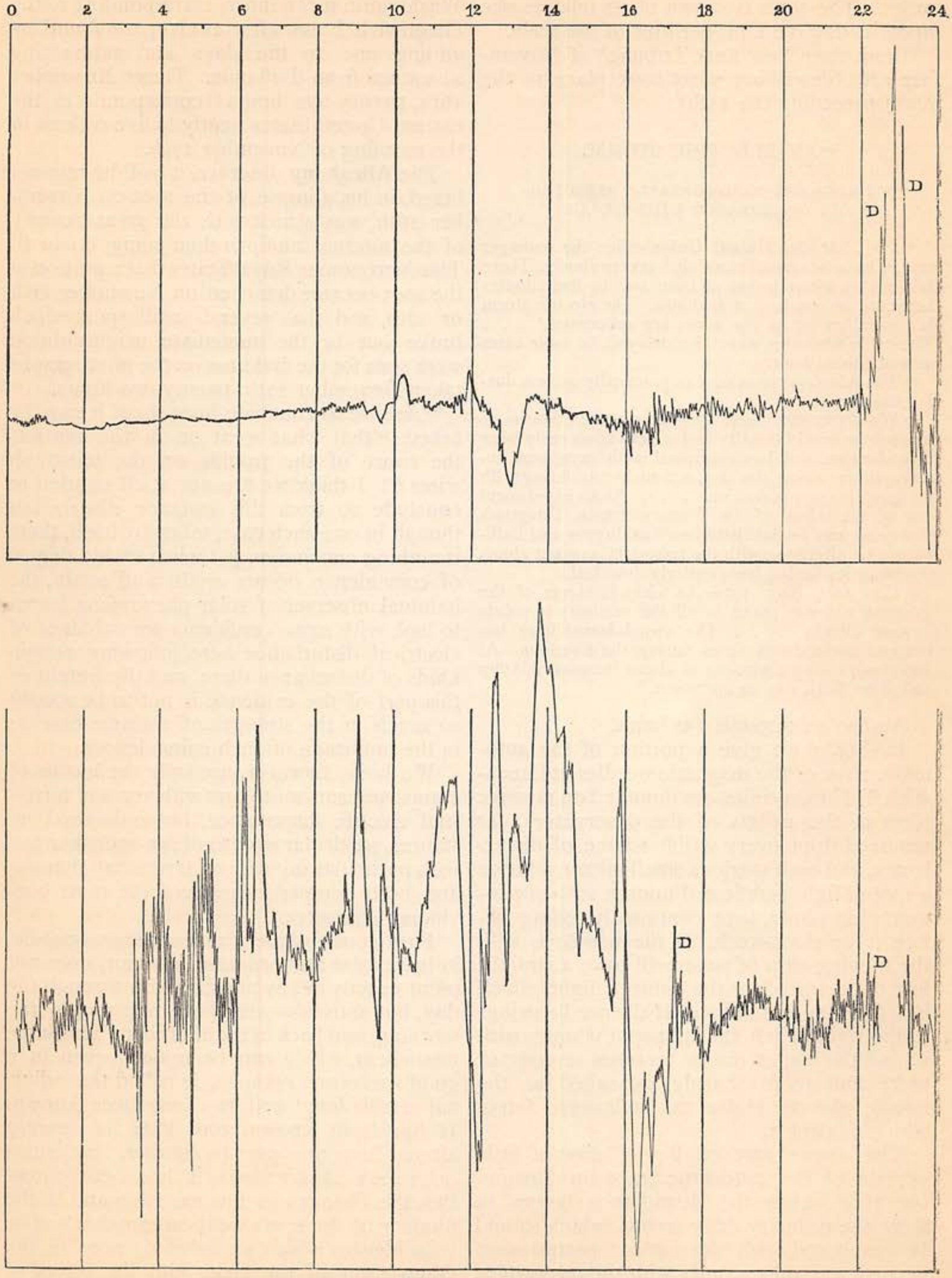

FIG. 3.—GREENWICH RECORD OF DISTURBANCE OF MAGNETIC NEEDLE, NOVEMBER 16th AND 17th, 1882.

square miles; at Greenwich its area, inclusive of some out-lying portions, was estimated on the same day to be 2,600,000,000 square miles. The earth is shown of its relative size upon it, to gave a proper idea of the scale.

From the "New York Tribune" of November 18th (describing what took place in the night preceding the 17th):

"AN ELECTRIC STORM.

"TELEGRAPH WIRES GREATLY AFFECTED.
THE DISTURBANCE WIDE-SPREAD.

". . . At the Mutual Union office the manager said, 'Our wires are all running, but very slowly. There is often an intermission of from one to five minutes between the words of a sentence. The electric storm is general as far as our wires are concerned.' . . . The cable messages were also delayed, in some cases as much as an hour.

"The telephone service was practically useless during the day.

"WASHINGTON, Nov. 17.—A magnetic storm of more than usual intensity began here at an early hour this morning, and has continued with occasional interruptions during the day, seriously interfering with telegraphic communication. . . . As an experiment one of the wires of the Western Union Telegraph Company was worked between Washington and Baltimore this afternoon with the terrestrial current alone, the batteries having been entirely detached.

"CHICAGO, Nov. 17.—An electric storm of the greatest violence raged in all the territory to points beyond Omaha. . . . The switch-board here has been on fire a dozen times during the forenoon. At noon only a single wire out of fifteen between this city and New York was in operation."

And so on through a column.

In Fig. 3 we give a portion of the automatic trace of the magnetic needles at Greenwich.* These needles are mounted on massive piers in the cellars of the observatory, far removed from every visible source of disturbance, and each carries a small mirror, whence a spot of light is reflected upon a strip of photographic paper, kept continually rolling before it by clock-work. If the needle is still, the moving strip of paper will have a straight line on it, traced by the point of light, which is in this case motionless. If the needle swings to the right or left, the light-spot vibrates with it, and the line it traces becomes sinuous, or more and more sharply zigzagged as the needle shivers under the unknown forces which control it.

The upper part of Fig. 3 gives a little portion of this automatic trace on November 16th before the disturbance began, to show the ordinary daily record, which should be compared with the violent perturbation occurring simultaneously with the telegraphic disturbance in the United States. We may, for the reader's convenience, remark that as the astronomical day begins twelve hours later than the civil day, the approximate Washington mean times, corresponding to the Greenwich hours after twelve, are found by adding one to the days and subtracting seventeen from the hours. Thus "November 16th, twenty-two hours" corresponds in the eastern United States nearly to five o'clock in the morning of November 17th.

The Allegheny observer, it will be remembered, in his glimpse of the spot on November 16th, was struck with the great activity of the internal motions then going on in it. The Astronomer Royal states that a portion of the spot became detached on November 17th or 18th, and that several small spots which broke out in the immediate neighborhood were seen for the first time on the photographs taken November 17th, twenty-two hours.

"Are we to conclude from this," it may be asked, "that what went on in the sun was the cause of the trouble on the telegraph wires?" I think we are not at all entitled to conclude so from this instance *alone*; but though in one such case, taken by itself, there is nothing conclusive, yet when such a degree of coincidence occurs again and again, the habitual observer of solar phenomena learns to look with some confidence for evidence of electrical disturbance here following certain kinds of disturbance there, and the weight of this part of the evidence is not to be sought so much in the strength of a single case as in the multitude of such coincidences.

We have, however, not only the means of comparing sun-spot *years* with years of terrestrial electric disturbance, but individual instances, particular *minutes* of sun-spot changes, with particular minutes of terrestrial change; and both comparisons are of the most convincing character.

First let us observe that the compass needle, in its regular and ordinary behavior, does not point exactly in any one direction through the day, but moves a very little one way in the morning, and back in the afternoon. This same movement, which can be noticed even in a good surveyor's compass, is called the "diurnal oscillation," and has long been known. It has been known, too, that its amount altered from one year to another, but since Schwabe's observations it has been found that the changes in this variation and in the number of the spots went on together. The coincidences which we failed to note in the comparison of the spots with the prices of grain are here made out with convincing

* It appears here through the kindness of the Astronomer Royal. We regret to say that American observers are dependent on the courtesy of foreign ones in such matters, the United States having no observatory where such records of sun-spots and magnetic variation are systematically kept.

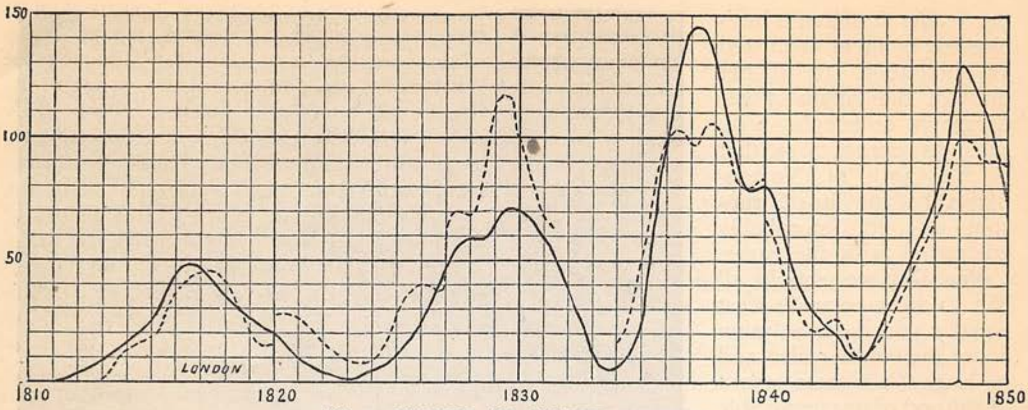

FIG. 4.—SUN-SPOTS AND MAGNETIC VARIATIONS.

clearness, as the reader will see by a simple inspection of this chart (Fig. 4, taken from Prof. Young's work), where the horizontal divisions still denote years, and the height of the continuous curve the relative number of spots, while the height of the dotted curve is the amount of the magnetic variation. Though we have given but a part of the curve, the presumption from the agreement in the forty years alone would be a strong one that the two effects, apparently so widely remote in their nature, are really due to a common cause.

Here we have compared years with years; let us next compare minutes with minutes. Thus, to cite (from Mr. Proctor's work) a well-known instance: On September 1st, 1869, at eighteen minutes past eleven, Mr. Carrington, an experienced solar observer, suddenly saw in the sun something brighter than the sun — two patches of light, breaking out so instantly and so intensely that his first thought was that daylight was entering through a hole in the darkening screen he used. It was immediately certain that something unusual was occurring in the sun itself, across which the brilliant spots were moving, traveling 35,000 miles in five minutes, at the end of which time (at twenty-three minutes past eleven) they disappeared from sight. By good fortune, another observer a few miles distant saw and independently described the same phenomenon; and as the minute had been noted, it was immediately afterward found that recording instruments registered a magnetic disturbance at the same time, — "at the very moment," says Dr. Stewart, the director of the observatory at Kew.

"By degrees," says Sir John Herschel, "accounts began to pour in of . . . great electro-magnetic disturbances in every part of the world. . . . At Washington and Philadelphia, in America, the telegraphic signal men received severe electric shocks. At Boston, in North America, a flame of fire followed the pen of Bain's electric telegraph." (Such electric disturbances, it may be mentioned, are called "electric storms," though when they occur the weather may be perfectly serene to the eye. They are shown also by rapid vibrations of the magnetic needle, like those we have illustrated.)

On August 3d, 1872, Professor Young, who was observing at Sherman in the Rocky Mountains, saw three notable paroxysms in the sun's chromosphere, jets of luminous matter of intense brilliance being projected at 8h. 45m., 10h. 30m., and 11h. 50m. of the local time. "At dinner," he says, "the photographer of the party, who was making our magnetic observations, told me, before knowing anything about what I had been observing, that he had been obliged to give up work, his magnet having swung clear off the limb." Similar phenomena were observed August 5th. Professor Young wrote to England, and received from Greenwich and Stonyhurst copies of the automatic record, which he gives, and which we give in Fig. 5. After allowing for difference of longitude, the reader who will take the pains to compare them may see for himself that both show a jump of the needles in the cellars at Greenwich at the same *minute* in each of the four cases of outburst in the Rocky Mountains.

While we admit that the evidence in any single case is rarely so conclusive as in these, while we agree that the spot is not so much the cause of the change as the index of some other solar action which does cause it, and while we fully concede our present ignorance of the nature of the cause, we cannot refuse to accept the cumulative evidence of which a little has been submitted.

It is only in rare cases that we can feel quite sure; and yet, in regard even to one of the more common and less conclusive ones, we may at least feel warranted in saying that if

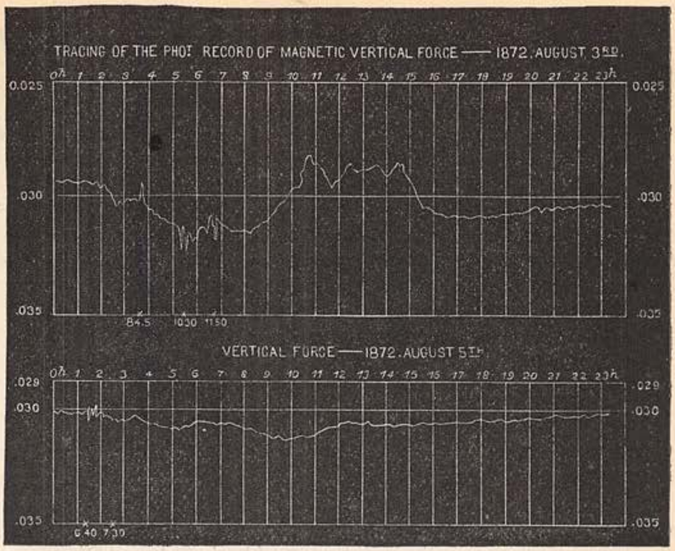

FIG. 5.—GREENWICH MAGNETIC OBSERVATIONS, AUGUST 3d AND 5th, 1872.

the reader forfeited a business engagement or missed an invitation to dinner through the failure of the telegraph or telephone on such an occasion as that of the 17th of November, 1882, the far-off sun-spot was not improbably connected with the cause.

Probably we should all like to hear some at least equally positive conclusion about the weather, also, and to learn that there was a likelihood of our being able to predict it for the next year, as the Signal Service now does for the next day; but there is at present no such likelihood. The study of the possible connection between sun-spots and the weather is, nevertheless, one that will always have great interest to many; for, even if we set its scientific aim aside and consider it in its purely utilitarian aspect, it is evident that the knowledge how to predict whether coming harvests would be good or bad would enable us to do for the whole world what Joseph's prophetic vision of the seven good and seven barren years did for the land of Egypt, and confer a greater power on its discoverer than any sovereign now possesses. There is something to be said, then, for the cyclists; for if their zeal does sometimes outrun knowledge, their object is a worthy one, and their aims such as we can sympathize with, and of which none of us can say that there is any inherent impossibility in them, or that they may not conceivably yet lead to something. Let us not, then, treat the inquirer who tries to connect panics on 'Change with sun-spots as a mere lunatic; for there is this amount of reason in his theory, that the panics, together with the general state of business, are connected in some obscure way with the good or bad harvests, and these again in some still obscurer way with changes in our sun.

We may leave, then, this vision of forecasting the harvests and the markets of the world from a study of the sun, as one of the fair dreams for our science's future. Perhaps the dream will one day be realized. Who knows?

If we paused on the last words, the reader might perhaps so far gather an impression that the whole all-important subject of the solar energy was involved in mystery and doubt. But if it be indeed a mystery when considered in its essence, so are all things; while regarded separately in any one of its terrestrial effects of magnetic or chemical action, or light or heat, it may seem less so. Since there is not room to consider all these aspects, let us choose the last, and look at this energy in its familiar form of the *heat* by which we live.

We, the human race, are warming ourselves at this great fire which called our bodies into being, and when it goes out we shall go too. What is it? How long has it been? How long will it last? How shall we use it?

To look across the space of over ninety million miles, and to try to learn from that distance the nature of the solar heat, and how it is kept up, seemed to the astronomers of the last century a hopeless task. The difficulty was avoided rather than met by the doctrine that the sun was pure fire, and shone because "it was its nature to." In the middle ages such an idea was universal; and along with it, and as a logical sequence of it, the belief was long prevalent that it was possible to make another such flame here, in the form of a lamp which should burn forever and radiate light endlessly without exhaustion. With the philosopher's stone, which was to transmute lead into gold, this perpetual lamp formed a prime object of research for the alchemist and student of magic.

We recall the use which Scott has made of the belief in this product of "gramarye" in the "Lay of the Last Minstrel," where it is sought to open the grave of the great wizard in Melrose Abbey. It is midnight when the stone which covers it is heaved away, and Michael's undying lamp, buried

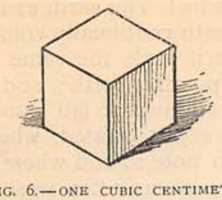

FIG. 6.—ONE CUBIC CENTIMETER.

with him long ago, shines out from the open tomb and illuminates the darkness of the chancel.

> "I would you had been there to see
> The light break forth so gloriously;
> That lamp shall burn unquenchably
> Until the eternal doom shall be,"

says the poet. Now we are at liberty to enjoy the fiction as a fiction; but if we admit that the art which could make such a lamp would indeed be a black art, which did not work under nature's laws, but against them, then we ought to see that, as the whole conception is derived from the early notion of a miraculous constitution of the sun, the idea of an eternal self-sustained sun is no more permitted to us than that of an eternal self-sustained lamp. We must look for the cause of the sun's heat in nature's laws, and we know those laws chiefly by what we see here.

Before examining the source of the sun's heat, let us look a little more into its amount. To find the exact amount of heat which it sends out is a very difficult problem, especially if we are to use all the refinements of the latest methods in determining it. The underlying principle, however, is embodied in an old method which gives, it is true, rather crude results, but by so simple a treatment that the reader can follow it readily, especially if unembarrassed with details, in which most of the actual trouble lies. We must warn him in advance that he is going to be confronted with a kind of enormous sum in multiplication, for whose general accuracy he may, however, trust to us if he pleases. We have not attempted exact accuracy, because it is more convenient for him that we should deal with round numbers.

The apparatus which we shall need for the attack of this great problem is surprisingly simple, and moderate in size. Let us begin by finding how much sun-heat falls in a small known area. To do this we take a flat, shallow vessel, which is to be filled with water. The amount it contains is usually a hundred cubic centimeters (a centimeter being nearly four-tenths of an inch), so that if we imagine a tiny cubical box about as large as a backgammon die, or, more exactly, having each side just the size of this (Fig. 6), to be filled and emptied into the vessel one hundred times, we shall have a precise idea of its limited capacity. Into this vessel we dip a thermometer, so as to read the temperature of the water, seal all up so that the water shall not run out, and expose it so that the heat at noon falls perpendicularly on it. The apparatus is shown in Fig. 7, attached to a tree. The stem of the instrument holds the thermometer, which is upside down, its bulb being in the water-vessel. Now all the sun's rays do not reach this vessel, for some are absorbed by our atmosphere; and all the heat which falls on it does not stay there, as the water loses part of it by the contact of the air with the box outside, and in other ways. When allowance is made for these losses, we find that the sun's heat, if all retained, would have raised the temperature of the few drops of water which would fill a box the size of our little cube (according to these latest observations) nearly three degrees of the centigrade thermometer in one minute—a most insignificant result apparently, as a measure of what we have been told is the almost infinite heat of the sun! But if we think so, we are forgetting the power of numbers, of which we are about to have an illustration as striking in its way as that which Archimedes once gave with the grains of sand.

There is a treatise of his extant, in which he remarks (I cite from memory) that as some people believe it possible for numbers to express a quantity as great as that of the grains of sand upon the sea-shore, while others deny this, he shall show that they can express one even larger. To prove this beyond dispute, he begins with a single seed, beside which he ranges single grains of sand in a line, till he can give the number of these latter which equal its length. Next he ranges seeds beside each other till their number makes up the length of a span; then he counts the spans in a stadium, and the stadia in the whole world as known to the ancients, at each step expressing his results in a number certainly *greater* than the number of sand-grains which the seed, or the span, or the stadium, or finally the whole world, is thus successively shown to contain. He has then already got a number before his reader's eyes demonstrably larger than that of all the grains of sand on the sea-shore; yet he does not stop, but steps off the earth into space, to calculate and express a number *greater* than

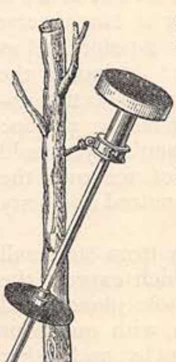

FIG. 7.—POUILLET'S PYRHELIOMETER.

that of all the grains of sand which would fill a sphere embracing the earth and the sun!

We are going to use our little unit of heat in the same way, for (to calculate in round figures and in English measure) we find that we can set over nine hundred of these small cubes side by side in a square foot, and, as there are 28,000,000 feet in a square mile, that the latter would contain 25,000,000,000 of the cubes, placed side by side, touching each other, like a mosaic pavement. We find also, by weighing our little cup, that we should need to fill and empty it almost exactly a million times to exhaust a tank containing a ton of water. The sun-heat falling on one square mile corresponds, then, to over seven hundred and fifty tons of water raised *every minute* from the freezing-point to boiling, which already is becoming a respectable amount!

But there are 49,000,000 square miles in the cross-section of the earth exposed to the sun's rays, which it would therefore need 1,225,000,000,000,000,000 of our little dies to cover one deep; and therefore in each *minute* the sun's heat falling on the earth would raise to boiling 37,000,000,000 tons of water.

We may express this in other ways, as by the quantity of ice it would melt; and as the heat required to melt a given weight of ice is $\frac{79}{100}$ of that required to bring as much water from the freezing to the boiling-point, and as the whole surface of he earth, including the night side, is four times the cross-section exposed to the sun, we find, by taking 526,000 minutes to a year, that the sun's rays would melt in the year a coating of ice over the whole earth more than one hundred and sixty feet thick.

We have ascended already from our small starting-point to numbers which express the heat that falls upon the whole planet, and enable us to deal, if we wish, with questions relating to the glacial epochs and other changes in its history. We have done this by referring at each step to the little cube which we have carried along with us, and which is the foundation of all the rest; and we now see why such exactness in the first determination is needed, since any error is multiplied by enormous numbers. But now we, too, are going to step off the earth and to deal with numbers which we can still express in the same way if we choose, but which grow so large thus stated that we will seek some greater term of comparison for them. We have just seen the almost incomprehensible amount of heat which the sun must send the earth in order to warm its oceans and make green its continents; but how little this is to what passes us by! The earth as it moves on in its annual path continually comes into new regions, where it finds the same amount of heat already pouring forth; and this same amount still continues to fall into the empty space we have just quitted, where there is no one left to note it, and where it goes on in what seems to us utter waste. If, then, the whole annual orbit were set close with globes like ours, and strung with worlds like beads upon a ring, each would receive the same enormous amount the earth does now. But this is not all; for not only along the orbit, but above and below it, the sun sends its heat in seemingly incredible wastefulness, the final amount being expressible in the number of *worlds* like ours that it could warm like ours, which is 2,200,000,000.

We have possibly given a surfeit of such numbers, but we cannot escape or altogether avoid them, when dealing with this stupendous outflow of the solar heat. They are too great, perhaps, to convey a clear idea to the mind, but let us before leaving them try to give an illustration of their significance.

Let us suppose that we could sweep up from the earth all the ice and snow on its surface, and, gathering in the accumulations which lie on its Arctic and Antarctic poles, commence building with it a tower greater than that of Babel, fifteen miles in diameter, and so high as to exhaust our store. Imagine that it could be preserved untouched by the sun's rays, while we built on with the accumulations of successive winters, until it stretched out 240,000 miles into space, and formed an ice-bridge to the moon, and that then we concentrated on it the sun's whole radiation, neither more nor less than that which goes on every moment. In *one* second the whole would be gone, melted, boiled and dissipated in vapor. And this is the rate at which the solar heat is being (to human apprehension) *wasted!*

Nature, we are told, always accomplishes her purpose with the least possible expenditure of energy. Is her purpose here, then, something quite independent of man's comfort and happiness? Of the whole solar heat, we have just seen that less than $\frac{1}{2,000,000,000}$—less, that is, than the one twenty-thousandth part of one per cent.—is made useful to us. "But may there not be other planets on which intelligent life exists, and where this heat, which passes us by, serves other beings than ourselves?" There *may* be; but if we could suppose all the other planets of the solar system to be inhabited, it would help the matter very little; for the whole together intercept so little of the great sum, that all of it which nature bestows on man is still as nothing to what she bestows on some end—if end there be—which is to us as yet inscrutable.

How is this heat maintained? Not by the miracle of a perpetual self-sustained flame, we may be sure. But, then, by what fuel is such a fire fed? There can be no question of simple burning, like that of coal in the grate, for there is no source of supply adequate to the demand. The State of Pennsylvania, for instance, is underlaid by one of the richest coal-fields of the world, capable of supplying the consumption of the whole country at its present rate for more than a thousand years to come. If the source of the solar heat (whatever that is) were withdrawn, and we were enabled to carry this coal there and shoot it into the solar furnace fast enough to keep up the known heat-supply, so that the solar radiation would go on at just its actual rate, the time which this coal would last is easily calculable. It would not last days or hours, but the whole of these coal-beds would demonstrably be used up in rather less than one one-thousandth of a second! We find by a similar calculation that if the sun were itself one solid block of coal, it would have burned out to the last cinder in less time than man has certainly been on the earth. But during historic times there has as surely been no noticeable diminution of the sun's heat, for the olive and the vine grow just as they did three thousand years ago, and the hypothesis of an actual burning becomes untenable. It has been supposed by some that meteors striking the solar surface might generate heat by their impact, just as a cannon-ball fired against an armor-plate causes a flash of light, and a heat so sudden and intense as to partly melt the ball at the instant of concussion. This is probably a real source of heat-supply as far as it goes, but it cannot go very far; and, indeed, if our whole world should fall upon the solar surface like an immense projectile, gathering speed as it fell, and finally striking (as it would) with the force due to a rate of over three hundred miles a second, the heat developed would supply the sun for but little more than sixty years.*

It is not necessary, however, that a body should be moving rapidly to develop heat, for arrested motion always generates it, whether the motion be fast or slow, though in the latter case the mass arrested must be larger to produce the same result. It is in the slow settlement of the sun's own substance toward its center, as it contracts in cooling, that we find a sufficient cause for the heat developed.

This explanation is often unsatisfactory to those who have not studied the subject, because the fact that heat so generated is not made familiar to most of us by observation.

Perhaps the following illustration will make the matter plainer. When we are carried up in a lift, or elevator, we know well enough that heat has been expended under the boiler of some engine to drag us up against the power of gravity. When the elevator is at the top of its course, it is ready to give out in descending just the same amount of power needed to raise it, as we see by its drawing up a nearly equal counterpoise in the descent. It can and must give out in coming down the power that was spent in raising it up; and though there is no practical occasion to do so, a large part of this power could, if we wished, be actually recovered in the form of heat again. In the case of a larger body, such as the pyramid of Ghizeh, which weighs between 6,000,000 and 7,000,000 tons, all the furnaces in the world, burning coal under all its engines, would have to supply their heat for a measurable time to lift it a mile high; and then, if it were allowed to come down, whether it fell at once or were made to descend with imperceptible slowness, by the time it touched the earth the same heat would be given out again.

Perhaps the fact that the sun is gaseous rather than solid makes it less easy to realize the enormous weight which is consistent with this vaporous constitution. A cubic mile of hydrogen gas (the lightest substance known) would weigh much more at the sun's surface than the Great Pyramid does here, and the number of these cubic miles in a stratum one mile deep below its surface is over 2,000,000,000,000! This alone is enough to show that, as they settle downward as the solar globe shrinks, here is a *possible* source of supply for all the heat the sun sends out. Exacter calculation shows that it *is* sufficient, and that a contraction of 300 feet a year (which in 10,000 years would make a shrinkage hardly visible in the most powerful telescope) would give all the immense outflow of heat we see.

There is an ultimate limit, however, to the sun's shrinking, and there must have been some bounds to the heat he can already have thus acquired; for—though the greater the original diameter of his sphere, the greater the gain of heat by shrinking to its present size—if the original diameter be supposed as great as possible, there is still a finite limit to the heat gained.

Suppose, in other words, the sun itself and all the planets ground to powder, and distributed on the surface of a sphere whose radius is infinite, and that this matter (the same

* These estimates differ somewhat from those of Helmholtz and Tyndall, as they rest on later measures.

in amount as that constituting the present solar system) is allowed to fall together at the center. The actual shrinkage cannot possibly be greater than in this extreme case; but even in this practically impossible instance, it is easy to calculate that the heat given out would not support the present radiation over 18,000,000 years, and thus we are enabled to look back over past time and fix an approximate limit to the present age of the sun and earth.

If we would look into the future, also, we find that at the present rate we may say that the sun's heat-supply is enough to last for some such term as four or five million years before it sensibly fails; for so long as the sun is purely gaseous, it actually grows hotter instead of cooler as it contracts; that is, there is less potential but more actual heat in it. It is certainly remarkable that by the aid of our science man can look out from this "bank and shoal of time," where his fleeting existence is spent, not only back on the almost infinite lapse of ages past, but that he can forecast with some sort of assurance what is to happen in an almost infinitely distant future, long after the human race itself will have disappeared from its present home. But so it is, and we may say — with something like awe at the meaning to which science points — that the whole past of the sun cannot then have been over 18,000,000 years, and its whole future radiation cannot last so much more. Its probable life is covered by about 30,000,000 years. No reasonable allowance for the fall of meteors or for all other known causes of supply could possibly raise the whole term of its existence to 60,000,000 years.

This is substantially Professor Young's view, and he adds: "At the same time it is, of course, impossible to assert that there has been no catastrophe in the past — no collision with some wandering star . . . producing a shock which might in a few hours, or moments even, restore the wasted energy of ages. Neither is it wholly safe to assume that there may not be ways, of which we as yet have no conception, by which the energy apparently lost in space may be returned. But the whole course and tendency of nature, so far as science now makes out, points backward to a beginning and forward to an end. The present order of things seems to be bounded both in the past and in the future by terminal catastrophes which are veiled in clouds as yet inscrutable."

THERE is another matter of interest to us as dwellers on this planet, connected not with the amount of the sun's heat so much as with the degree of its temperature; for it is almost certain that a very little fall in the temperature will cause an immense and wholly disproportionate diminution of the heat-supply. The same principle may be observed in more familiar things. We can, for instance, warm quite a large house by a very small furnace, if we urge this (by a wasteful use of coal) to a dazzling white heat. If we now let the furnace cool to half this white-heat temperature, we shall be sure to find that the heat radiated has not diminished in proportion, but out of all proportion, — has sunk, for instance, not only to one-half what it was (as we might think it would do), but to perhaps a twentieth or even less, so that the furnace which heated the house can no longer warm a single room.

The human race, as we have said, is warming itself at the great solar furnace, which we have just seen contains an internal source for generating heat enough for millions of years to come; but we have also learned that if the sun's internal circulation were stopped, the surface would cool and shut up the heat inside, where it would do us no good. The *temperature* of the surface, then, on which the rate of heat-emission depends, concerns us very much; and if we had a thermometer so long that we could dip its bulb into the sun and read the degrees on the stem here, we should find out what observers would very much like to know, and at present are disposed to quarrel about. The difficulty is not in measuring the heat, — for that we have just seen how to do, — but in telling what temperature corresponds to it, since there is no known rule by which to find one from the other. One certain thing is this — that we cannot by any contrivance raise the temperature in the focus of any lens or mirror beyond that of its source (practically we cannot do even so much); we cannot, for instance, by any burning-lens make the image of a candle as hot as the original flame. Whatever a thermometer may read when the candle-heat is concentrated on its bulb by a lens, it would read yet more if the bulb were dipped in the candle-flame itself; and one obvious application of this fact is that, though we cannot dip our thermometer in the sun, we know that if we could do so the temperature would at least be greater than any we get by the largest burning-glass. We need have no fear of making the burning-glass too big; the temperature at its solar focus is *always* and necessarily lower than that of the sun itself.

For some reason no very great burning-lens or mirror has been constructed for a long time, and we have to go back to the eighteenth century to see what can be done in this way. The annexed figure (Fig. 8) is from a wood-cut of the last century, describing the largest burning-lens then or since constructed

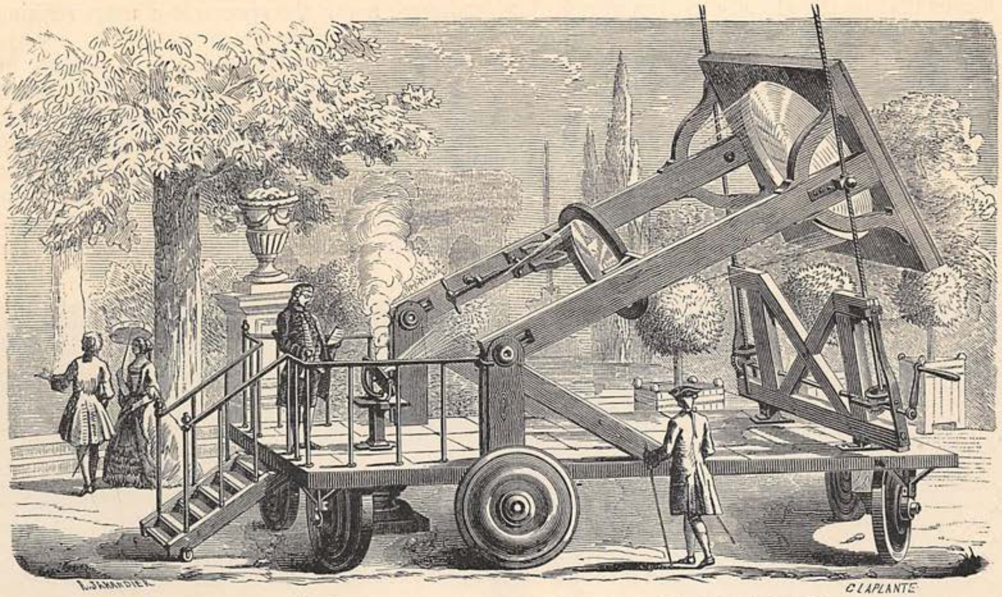

FIG. 8.—BERNIÈRES'S GREAT BURNING-GLASS. (AFTER AN OLD FRENCH PRINT.)

in France, whose size and mode of use the drawing clearly shows. All the heat falling on the great lens was concentrated on a smaller one, and the smaller one concentrated it in turn, till at the very focus we are assured that iron, gold, and other metals ran like melted butter. In England, the largest burning-lens on record was made about the same time by an optician named Parker for the English Government, who designed it as a present to be taken by Lord Macartney's embassy to the Emperor of China. Parker's lens was three feet in diameter and very massive, being seven inches thick at the center. In its focus the most refractory substances were fused, and even the diamond was reduced to vapor, so that the temperature of the sun's surface is at any rate higher than *this*.

(What became of the French lens shown, it would be interesting to know. If it is still above ground, its fate has been better than that of the English one. It is said that the Emperor of China, when he got his lens, was much alarmed by it, as being possibly sent him by the English with some covert design for his injury. By way of a test, a smith was ordered to strike it with his hammer; but the hammer rebounded from the solid glass, and this was taken to be conclusive evidence of magic in the thing, which was immediately buried, and probably is still reposing under the soil of the Celestial Flowery Kingdom.)

We can confirm the evidence of such burning-lenses as to the sun's high temperature by another class of experiment, which rests on an analogous principle. We can make the comparison between the heat from some artificially heated object and that which would be given out from an equal area of the sun's face. Now, supposing like emissive powers, if the latter be found the hotter, though we cannot tell what its temperature absolutely is, we can at least say that it is greater than that of the thing with which it is compared; so that we choose for comparison the hottest thing we can find, on a scale large enough for the experiment. One observation of my own in this direction I will permit myself to cite in illustration.

Perhaps the highest temperature we can get on a large scale in the arts is that of molten steel in the Bessemer converter. As many may be as ignorant of what this is as I was before I tried the experiment, I will try to describe it.

The "converter" is an enormous iron pot, lined with fire-brick, and capable of holding thirty or forty thousand pounds of melted metal; and it is swung on trunnions, so that it can be raised by an engine to a vertical position, or lowered by machinery so as to pour its contents out into a caldron. First the empty converter is inclined, and fifteen thousand pounds of fluid iron streams down into the mouth from an adjacent furnace where it has been melted. Then the engine lifts the converter into an erect position, while an air-blast from a blowing-engine is forced in at the bottom and through the liquid iron, which has combined with it nearly half a ton of silicon and carbon,— materials which, with the oxygen of the blast, create a heat which leaves that of the already molten iron far behind. After some time the converter is tipped forward, and fifteen hundred pounds more of melted iron is added to that already in it. What the temperature of this last is, may be judged from the fact that though a stream of ordinary melted iron is dazzlingly bright, the melted metal in the converter is so much brighter still that the entering stream is dark brown by comparison, presenting a contrast like that of chocolate poured into a white cup. The contents are now no longer iron, but liquid steel, ready for pouring into the caldron; and, looking from the front down into the inclined vessel, we see the almost blindingly bright interior dripping with the drainage of the metal running down its side, so that the circular mouth, which is twenty-four inches in diameter, presents the effect of a disk of molten metal of that size (were it possible to maintain such a disk in a vertical position). In addition, we have the actual stream of falling metal, which continues nearly a minute, and presents an area of some square feet. The shower of scintillations from this cataract of what seems at first "sun-like" brilliancy, and the area whence such intense heat and light are for a brief time radiated, make the spectacle a most striking one. (See Fig. 9.)

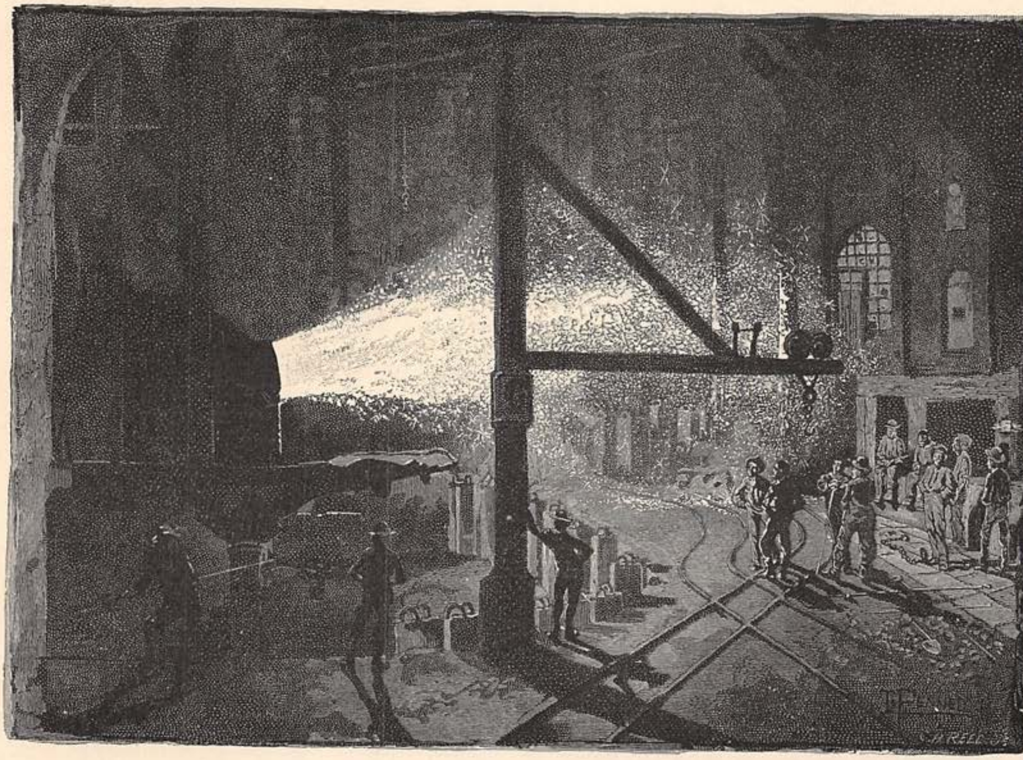

FIG. 9.—A "POUR" FROM THE BESSEMER CONVERTER.

The "pour" is preceded by a shower of sparks, consisting of little particles of molten steel which are projected fully a hundred feet in the direction of the open mouth of the converter. In the line of this my apparatus was stationed in an open window, at a point where its view could be directed down into the converter on one side, and up at the sun on the other. This apparatus consisted of a long photometer-box with a *porte-lumière* at one end. The mirror of this reflected the sun's rays through the box and then on to the pouring metal, tracing their way to it by a beam visible in the dusty air (Fig. 10). In the path of this beam was placed the measuring apparatus, both for heat and light. As the best point of observation was in the line of the blast, a shower of sparks was driven over the instrument and observer at every "pour"; and the rain of wet soot from chimneys without, the bombardment from within, and the moving masses of red-hot iron around, made the experiment an altogether peculiar one. The apparatus was arranged in such a way that the effect (except for the absorption of its beams on the way) was independent of the size or distance of the sun, and depended on the absolute radiation there, and was equivalent, in fact, to taking a sample piece of the sun's face *of equal size* with the fluid metal, bringing them face to face, and seeing which was the hotter and brighter. The comparison, however, was unfair to the sun, because its rays were in reality partly absorbed by the atmosphere on the way, while those of the furnace were not. Under these circumstances the heat from any single square foot of the sun's surface was found to be *at least* eighty-seven times that from a square foot of the melted metal, while the light from the sun was proved to be, foot for foot, over five thousand times that from the molten steel, though the latter, separately considered, seemed to be itself, as I have said, of quite sun-like brilliancy.

We must not conclude from this that the *temperature* of the sun was five thousand times that of the steel, but we may be certain that it was at any rate a great deal the higher of the two. It is probable, from all experiments made up to this date, that the solar effective temperature is not less than 3000 nor more than 30,000 degrees of the centigrade thermometer. Sir William Siemens, whose opinion on any question as to heat is entitled to great respect, thought the lower value nearer the truth, but this is doubtful.

We have, in all that has preceded, been speaking of the sun's constitution and appearance, and have hardly entered on the question of its industrial relations to man. It must be evident, however, that if we derive, as it is asserted we do, almost all our mechanical power from this solar heat,—if our water-wheel is driven by rivers which the sun feeds by the rain he sucks up for them into the clouds, if the coal is stored sun-power, and if, as Stevenson said, it really is the sun which drives our engines, though at second hand,—there is an immense fund of possible mechanical power still coming to us from him which might be economically utilized. Leaving out of sight all our more important relations to him (for, as has been already said, he is in a physical sense our creator, and he keeps us alive from hour to hour), and considering him only as a possible servant to grind our corn and spin our flax, we find that even in this light there are startling possibilities of profit in the study of our subject. From recent measures it appears that from every square yard of the earth exposed perpendicularly to the sun's rays, in the absence of an absorbing atmosphere there could be derived more than one horse-power, if the heat were all converted into this use, and that even on such a little area as the island of Manhattan, or that occupied by the city of London, the noontide heat is enough, could it all be utilized, to drive all the steam-engines in the world. It will not be surprising, then, to hear that many practical men are turning their attention to this as a source of power, and that, though it has hitherto cost more to utilize the power than it is worth, there is reason to believe that some of the greatest changes which civilization has to bring may yet be due to such investigations. The visitor to the last Paris Exposition may remember an extraordinary machine on the grounds of the Trocadéro looking like a gigantic inverted umbrella pointed sunward. This was the sun-machine of M. Mouchot, consisting of a great parabolic reflector which concentrated the heat on a boiler in the focus and drove a steam-engine with it, which was employed in turn to work a printing-press as our engraving shows (Fig. 11). Because these constructions have been hitherto little more than playthings, we are not to think of them as useless. If toys, they are the toys of the childhood of a science which is destined to grow, and in its maturity to apply this solar energy to the use of all mankind.

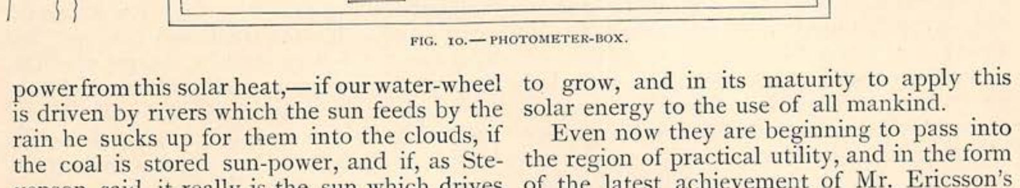

FIG. 10.—PHOTOMETER-BOX.

Even now they are beginning to pass into the region of practical utility, and in the form of the latest achievement of Mr. Ericsson's ever-young genius are ready for actual work on an economical scale. We present in Fig. 12 his new actually working solar engine, which there is every reason to believe is more efficient than Mouchot's, and probably capable of being used with economical advantage

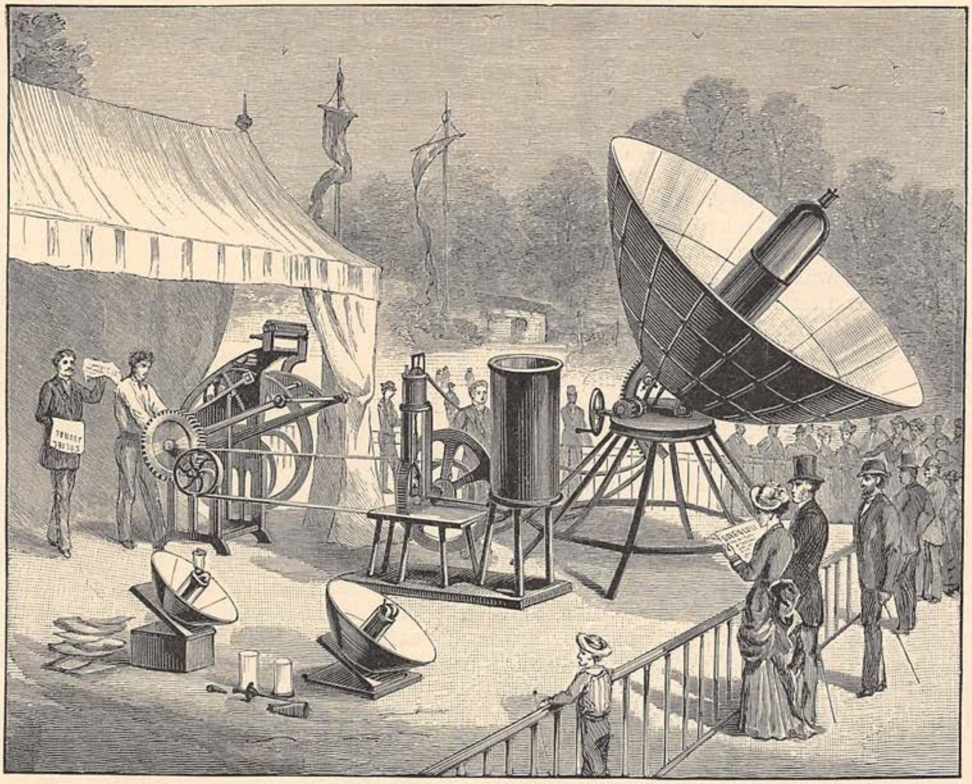

FIG. 11.—MOUCHOT'S SOLAR ENGINE. (FROM A FRENCH PRINT.)

in pumping water in desert regions of our own country. It is pregnant with suggestion of the future, if we consider the growing demand for power in the world, and the fact that its stock of coal, though vast, is strictly limited, in the sense that when it *is* gone we can get absolutely no more. The sun has been making a little every day for millions of years—so little and for so long that it is as though time had daily dropped a single penny into the bank to our credit for untold ages, until an enormous fund had been thus slowly accumulated in our favor. We are drawing on this fund like a prodigal who thinks his means endless, but the day will come when our check will no longer be honored, and what shall we do then?

The exhaustion of some of the coal-beds is an affair of the immediate future, by comparison with the vast period of time we have been speaking of. The English coal-beds, it is asserted, will, from present indications, be quite used up in about three hundred years more. Three hundred years ago the sun, looking down on the England of our forefathers, saw a fair land of green woods and quiet waters, a land unvexed with noisier machinery than the spinning-wheel, or the needles of the "free maids that weave their threads with bones." Because of the coal which has been dug from its soil, he sees it now soot-blackened, furrowed with railway-cuttings, covered with noisy manufactories, filled with grimy operatives, while the island shakes with the throb of coal-driven engines, and its once quiet waters are churned by the wheels of steamships. Many generations of the lives of men have passed to make the England of Elizabeth into the England of Victoria, but what a moment this time is compared with the vast lapse of ages during which the coal was being stored! What a moment in the life of the "all-beholding sun," who in a few hundred years—his gift exhausted and the last furnace-fire out—may send his beams through rents in the ivy-grown walls of deserted factories, upon silent engines brown with eating rust, while the mill-hand has gone to other lands, the rivers are clean again, the harbors show only white sails, and England's "black country" is green once more! To America, too, such a time, may come, though at a greatly longer distance.

Does this all seem but the idlest fancy? That something like it will come to pass sooner or later is a most certain fact—as certain

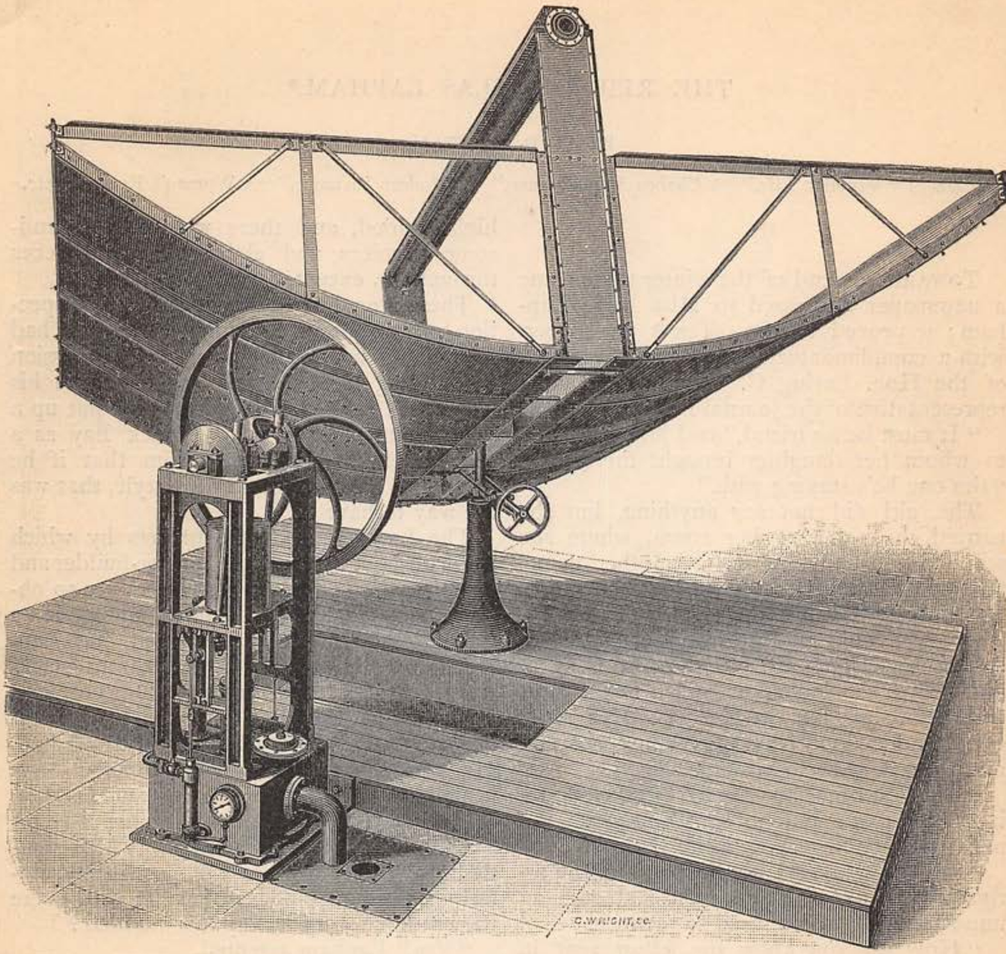

FIG. 12.—ERICSSON'S NEW SOLAR ENGINE, NOW IN PRACTICAL USE IN NEW YORK.

as any process of nature—if we do not find a new source of power; for of the coal which has supplied us, after a certain time we can get no more.

Future ages may see the seat of empire transferred to regions of the earth now barren and desolated under intense solar heat—countries which, for that very cause, will not improbably become the seat of mechanical and thence of political power. Whoever finds the way to make industrially useful the vast sun-power now wasted on the deserts of North Africa or the shores of the Red Sea, will effect a greater change in men's affairs than any conqueror in history has done; for he will once more people those waste places with the life that swarmed there in the best days of Carthage and of old Egypt, but under another civilization, where man no longer shall worship the sun as a god, but shall have learned to make it his servant.

S. P. Langley.

bug, and yet her knowledge had this imperfection, that he had never confessed it—a fact that was really grand when one thought of his opportunities for doing so. He had never allowed that he wasn't straight; the pair had so often been in the position of the two augurs behind the altar, and yet he had never given her a glance that the whole circle mightn't have observed. Even in the privacy of domestic intercourse he had phrases, excuses, explanations, ways of putting things, which, as she felt, were too sublime for just herself; they were pitched, as Selah's nature was pitched, altogether in the key of public life.

So it had come to pass, in her distended and demoralized conscience, that with all the things she despised in her life and all the things she rather liked, between being worn out with her husband's inability to earn a living and a kind of terror of his consistency (he had a theory that they lived delightfully), it happened, I say, that the only very definite criticism she made of him to-day was that he didn't know how to speak. That was where the shoe pinched — that was where Selah was slim. He couldn't hold the attention of an audience, he was not acceptable as a lecturer. He had plenty of thoughts, but it seemed as if he couldn't fit them into each other. Public speaking had been a Greenstreet tradition, and if Mrs. Tarrant had been asked whether in her younger years she had ever supposed she should marry a mesmeric healer, she would have replied: "Well, I never thought I should marry a gentleman who would be silent on the platform!" This was her most general humiliation; it included and exceeded every other, and it was a poor consolation that Selah possessed as a substitute —his career as a healer, to speak of none other, was there to prove it — the eloquence of the hand. The Greenstreets had never set much store on manual activity; they believed in the influence of the lips. It may be imagined, therefore, with what exultation, as time went on, Mrs. Tarrant found herself the mother of an inspired maiden, a young lady from whose lips eloquence flowed in streams. The Greenstreet tradition would not perish, and the dry places of her life would, perhaps, be plentifully watered. It must be added that, of late, this sandy surface had been irrigated, in moderation, from another source. Since Selah had addicted himself to the mesmeric mystery, their home had been a little more what the home of a Greenstreet should be. He had "considerable many" patients, he got about two dollars a sitting, and he had effected some most gratifying cures. A lady in Cambridge had been so much indebted to him that she had recently persuaded them to take a house near her, in order that Doctor Tarrant might drop in at any time. He availed himself of this convenience,—they had taken so many houses that another, more or less, didn't matter,— and Mrs. Tarrant began to feel as if they really had "struck" something.

(To be continued.)

Henry James.

THE NEW ASTRONOMY. IV.

THE PLANETS AND THE MOON.

WHEN we look up at the heavens, we see, if we watch through the night, the host of stars rising in the east and passing above us to sink in the west, always at the same distance and in unchanging order, each seeming a point of light as feeble as the glow-worm's shine in the meadow over which they are rising, each flickering as though the evening wind would blow it out. The infant stretches out its hand to grasp the Pleiades, but when the child has become an old man the "seven stars" are still there unchanged, dim only in his aged sight, and proving themselves the enduring substance, while it is his own life which has gone, as the shine of the glow-worm in the night. They were there just the same a hundred generations ago, before the Pyramids were built, and they will tremble there still when the Pyramids have been worn down to dust with the blowing of the desert sand against their granite sides. They watched the earth grow fit for man, long before man came, and they will doubtless be shining on when our poor human race itself has disappeared from the surface of this planet.

Probably there is no one of us who has not felt this solemn sense of their almost infinite duration as compared with his own little portion of time, and it would be a worthy subject for our thought if we could study them in the light that the new astronomy sheds for us on their nature. But I must here confine myself to the description of but a few of their number, and speak, not of the infinite multitude and variety

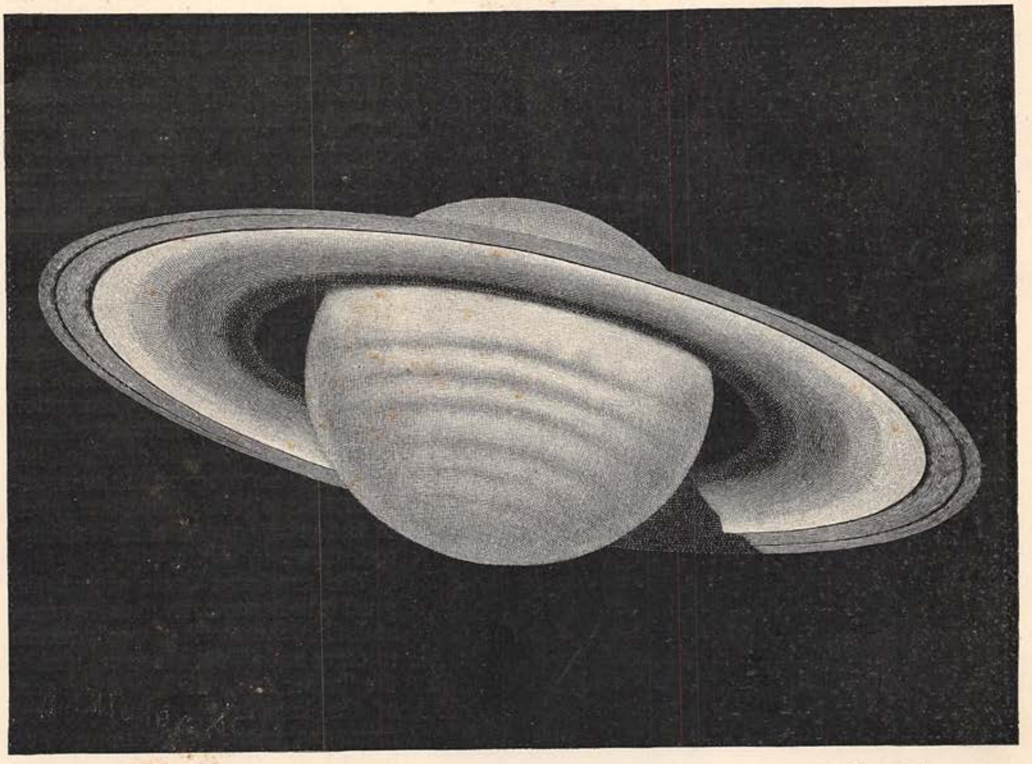

FIG. I.—SATURN. (FROM A DRAWING BY TROUVELOT, BY PERMISSION OF CHARLES SCRIBNER'S SONS.)

of stars, each a self-shining sun, but only of those which move close at hand; for it is not true of quite all that they keep at the same distance and order.

Of the whole celestial army which the naked eye watches, there are five stars which do change their places in the ranks, and these change in an irregular and capricious manner, going about among the others, now forward and now back, as if lost and wandering through the sky. These wanderers were long since known by distinct names, as Mercury, Venus, Mars, Jupiter, and Saturn, and believed to be nearer than the others; and they are, in fact, companions to the earth and fed like it by the warmth of our sun, and like the moon are visible by the sunlight which they reflect to us. With the earliest use of the telescope, it was found that while the other stars remained in it mere points of light as before, these became magnified into disks on which markings were visible, and the markings have been found with our modern instruments, in one case at least, to take the appearance of oceans and snow-capped continents and islands. These, then, are not uninhabitable self-shining suns, but worlds, vivified from the same fount of energy that supplies us, and the possible abode of creatures like ourselves.

"Properly speaking," it is said, "man is the only subject of interest to man"; and if we have cared to study the uninhabitable sun because all that goes on there is found to be so intimately related to us, it is surely a reasonable curiosity which prompts the question so often heard as to the presence of life on these neighbor worlds, where it seems at least not impossible that life should exist. Even the very little we can say in answer to this question will always be interesting, but we must regretfully admit at the outset that it is but little, and that with some planets, like Mercury and Venus, the great telescopes of modern times cannot do much more than those of Galileo, with which our new astronomy had its beginning.

Let us leave these, then, and pass out to the confines of the planetary system, where we may employ our telescopes to better advantage.

The outer planets, Neptune and Uranus, remain pale disks in the most powerful instruments, the first attended by a single moon, the second by four, barely visible; and there is so very little yet known about their physical features, that we shall do better to give our

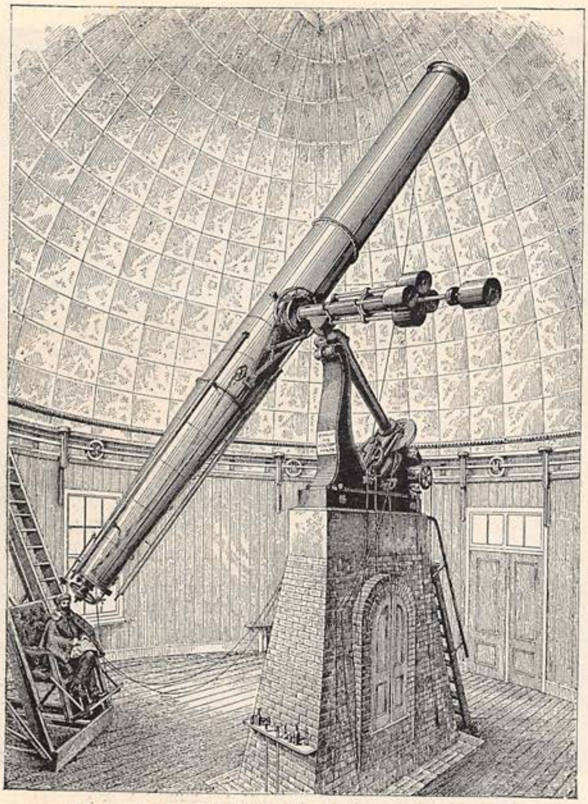

FIG. 2.—THE EQUATORIAL TELESCOPE AT WASHINGTON.

attention to one of the most interesting objects in the whole heavens—the planet Saturn, on which we can at any rate see enough to arouse a lively curiosity to know more.

When Galileo first turned his glass on Saturn, he saw, as he thought, that it consisted of three spheres close together, the middle one being the largest. He was not quite sure of the fact, and was in a dilemma between his desire to wait longer for further observation, and his fear that some other observer might announce the discovery if he hesitated. To combine these incompatibles—to announce it so as to secure the priority, and yet not announce it till he was ready—might seem to present as great a difficulty as the discovery itself; but Galileo solved this, as we may remember, by writing it in the sentence, "*Altissimum planetam tergeminum observavi*" ("I have observed the highest planet to be triple"), and then throwing it (in the printer's phrase) "into pi," or jumbling the letters, which made the sentence into the monstrous word

SMAJSMRMJLMEPOETALEVNJPVNENVGTTAVJRAS,

and publishing *this*, which contained his discovery, but under lock and key. He had reason to congratulate himself on his prudence, for within two years two of the supposed bodies disappeared, leaving only one. This was in 1612, and for nearly fifty years Saturn continued to all astronomers the enigma which it was to Galileo, till in 1656 it was finally made clear that it was surrounded by a thin flat ring, which when seen fully gave rise to the first appearance in Galileo's small telescope, and when seen edgewise disappeared from its view altogether. Everything in this part of our work depends on the power of the telescope we employ, and in describing the modern means of observation we pass over two centuries of slow advance, each decade of which has marked some progress in the instrument, to one of its completest types, in the great equatorial at Washington, shown in Fig. 2.

The revolving dome above, the great tube beneath, its massive piers, and all its accessories are only means to carry and direct the great lens at the further end, which acts the part of the lens in our own eye, and forms the image of the thing to be looked at. Galileo's original lens was a single piece of glass, rather smaller than that of our common spectacles; but the lens here is composed of two pieces, each twenty-six inches in diameter, and collects as much light as a human eye would do if over two feet across. But this is useless if the lens is not shaped with such precision as to send every ray to its proper place at the eye-piece, nearly thirty-five feet away; and, in fact, the shape given its surface by the skillful hands of the Messrs. Clark, who made it, is so exquisitely exact that all the light of a star gathered by this great surface is packed at the distant focus into a circle very much smaller than that made by the dot on this *i*,—a thing we might call incredible were it not certain. It is with instruments of such accuracy that astronomy now works, and it is with this particular one that some of the observations we are going to describe have been made.

In all the heavens there is no more wonderful object than Saturn, for it preserves to us an apparent type of the plan on which all the worlds were originally made. Let us look at it in this study by Trouvelot (Fig. 1). The planet, we must remember, is a globe nearly seventy thousand miles in diameter, and the outermost ring is over one hundred and fifty thousand miles across, so that the proportionate size of our earth would be over-represented here by a pea laid on the engraving. The belts on the globe show delicate tints of brown and blue, and parts of the ring are, as a whole, brighter than the planet; but this ring, as the reader may see, consists of at least three main divisions, each itself containing separate features. First is the gray outer ring, then the middle one, and next the curious "crape" ring, very much darker than the others, looking like a belt where it crosses the planet, and apparently feebly transparent, for the outline of the globe has been seen (though not very distinctly) *through* it. The whole system of rings is of the most amazing thinness, for it is probably thinner in proportion to its size than the paper on which this is printed is to the width of the page; and when it is turned edgewise to us, it disappears to all but the most powerful telescopes, in which it looks then like the thinnest conceivable line of light, on which the moons have been seen projected, appearing like beads sliding along a golden wire. The globe of the planet casts on the ring a shadow, which is here shown as a broken line, as though the level of the rings were suddenly disturbed. At other times (as in a beautiful drawing made with the same instrument by Professor Holden) the line seems continuous, though curved as though the middle of the ring system were thicker than the edge. The rotation of the ring has been made out by direct observations; and the whole is in motion about the globe,—a motion so smooth and steady that there is no flickering in the shadow "where Saturn's steadfast shade sleeps on its luminous ring."

FIG. 3.—JUPITER, MOON AND SHADOW. (BY PERMISSION OF WARREN DE LA RUE.)

What is it? No solid could hold together under such conditions; we can hardly admit the possibility of its being a liquid film extended in space; and there are difficulties in admitting it to be gaseous. But if not a solid, a liquid, or a gas, again what can it be? It was suggested nearly two centuries ago that the ring might be composed of innumerable little bodies like meteorites, circling round

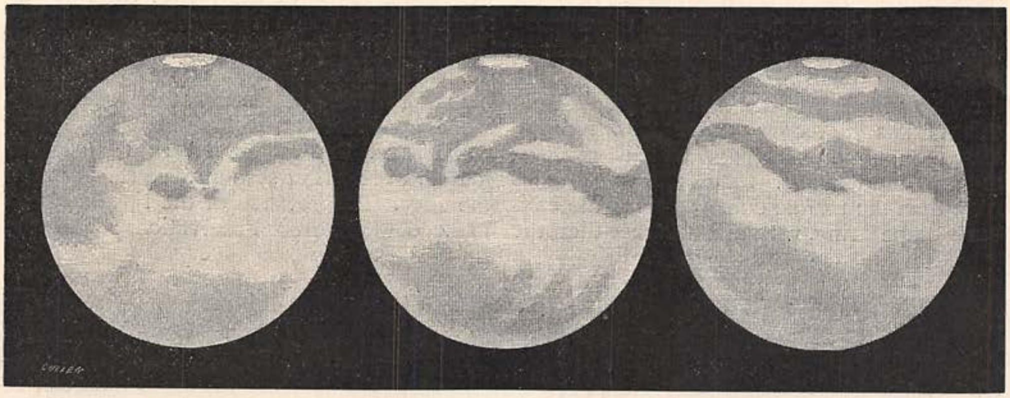

FIG. 4.—THREE VIEWS OF MARS.

the globe so close together as to give the appearance we see, much as a swarm of bees at a distance looks like a continuous cloud; and this remains the most plausible solution of what is still in some degree a mystery. Whatever it be, we see in the ring the condition of things which, according to the nebular hypothesis, once pertained to all the planets at a certain stage of their formation, and this, with the extraordinary lightness of the globe (for the whole planet would float on water), makes us look on it as still in the formative stage of uncondensed matter, where the solid land as yet is not, and the foot could find no resting-place. Astrology figured the planet as "spiteful and cold—an old man melancholy"; but if we may indulge such a speculation, modern astronomy rather leads us to think of it as in the infancy of its life, with every process of planetary growth still in its future, and separated by an almost unlimited stretch of years from the time when life under the conditions in which we know it can even begin to exist.

LIKE this appears also the condition of Jupiter (Fig. 3), the greatest of the planets, whose globe, eighty-eight thousand miles in diameter, turns so rapidly that the centrifugal force causes a visible flattening. The belts which stretch across its disk are of all delicate tints—some pale blue, some of a crimson lake; a sea-green patch has been seen, and at intervals of late years there has been a great oval red spot, which has now nearly gone, and which our engraving does not show. The belts are largely, if not wholly, formed of rolling clouds, drifting and changing under our eyes, though more rarely a feature like the oval spot just mentioned will last for years, an enduring enigma. The most recent observations tend to make us believe that the equatorial regions of Jupiter, like those of the sun, make more turns in a year than the polar ones; while the darkening toward the edge is another sun-like feature, though perhaps due to a distinct cause, and this is beautifully brought out when any one of the four moons which circle the planet passes between us and its face, an occurrence also represented in our figure. The moon, as

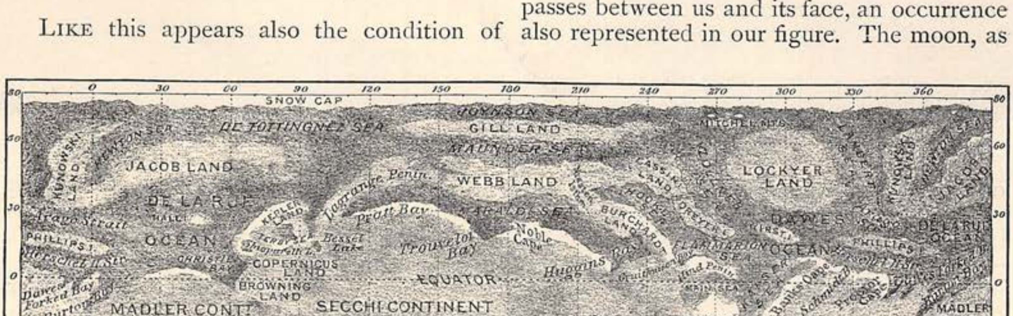

FIG. 5.—MAP OF MARS.

it steals on the comparatively dark edge, shows us a little circle of an almost lemon-yellow, but the effect of contrast grows less as it approaches the center. Next (or sometimes before) the disk is invaded by a small and intensely black spot, the shadow of the moon, which slides across the planet's face, the transit lasting long enough for us to see that the whole great globe, serving as a background for the spectacle, has visibly revolved on its axis since we began to gaze. Photography, in the skillful hands of the late Professor Henry Draper, gave us reason to suspect the possibility that a dull light is sent to us from parts of the planet's surface besides what it reflects, as though it were still feebly glowing like a nearly extinguished sun; and, on the whole, a main interest of these features to us lies in the presumption they create that the giant planet is not yet fit to be the abode of life, but is more probably in a condition like that of our earth millions of years since, in a past so remote that geology only infers its existence, and long before our own race began to be. That science teaches that such all but infinite periods are needed to prepare a planet for man's abode, that the entire duration of his race upon it is probably brief in comparison.

We pass by the belt of asteroids, and over a distance many times greater than that which separates the earth from the sun, till we approach our own world. Here, close beside it as it were, in comparison with the enormous spaces which intervene between it and Saturn and Jupiter, we find a planet whose size and features are in striking contrast to those of the great globe we have just quitted. It is Mars, which shines so red and looks so large in the sky because it is so near, but whose diameter is only about half that of our earth. This is indeed properly to be called a neighbor world, but the planetary spaces are so immense that this neighbor is at closest still about 34,000,000 miles away.

Looking across that great interval, we see in our engraving (Fig. 4) — where we have three successive views taken at intervals of a few hours — a globe not marked by the belts of Jupiter or Saturn, but with outlines as of continents and islands, which pass in turn before our eyes as it revolves in a little over twenty-four and a half of our hours, while at either pole is a white spot. Sir William Herschel was the first to notice that this spot increased in size when it was turned away from the sun and diminished when the solar heat fell on it, so that we have what is almost proof that here is ice (and consequently water) on another world. Then, as we study more, we discern forms which move from day to day on the globe apart from its rotation, and we recognize in them clouds sweeping over the surface — not a surface of still other clouds below, but of what we have good reason to believe to be land and water.

By the industry of numerous astronomers, seizing every favorable opportunity when Mars comes near, so many of these features have been gathered that we have been enabled to make fairly complete maps of the planet, one of which by Mr. Green is here given (Fig. 5).

Here we see the surface more diversified than that of our earth, while the oceans are long, narrow, canal-like seas, which everywhere invade the land, so that on Mars one could travel almost everywhere by water. The spectroscope indicates water-vapor in the Martial atmosphere, and some of the continents, like "Lockyer Land," are sometimes seen white, as though covered with ice; while one island (marked on our map as Hall Island) has been seen so frequently thus that it is very probable that here some mountain or table-land rises into the region of perpetual snow.

The cause of the red color of Mars has never been satisfactorily ascertained. Its atmosphere does not appear to be dark enough to produce such an effect, and perhaps as probable an explanation as any is one the suggestion of which is a little startling at first. It is that vegetation on Mars may be *red* instead of green! There is no intrinsic improbability in the idea, for we are even to-day unprepared to say with any certainty why vegetation is green here, and it is quite easy to conceive of atmospheric conditions which would make red the best absorber of the solar heat. Here, then, we find a planet on which we obtain many of the conditions of life which we know ourselves, and here, if anywhere in the system, we may allowably inquire for evidence of the presence of something like our own race; but though we may indulge in supposition, there is unfortunately no prospect that with any conceivable improvement in our telescopes we shall ever obtain anything like certainty. We cannot assert that there are any bounds to man's invention, or that science may not, by some means as unknown to us as the spectroscope was to our grandfathers, achieve what now seems impossible; but to our present knowledge no such means exist, though we are not forbidden to look at the ruddy planet with the feeling that it may hold possibilities more interesting to our humanity than all the wonders of the sun, and all the uninhabitable immensities of his other worlds.

Before we leave Mars, we may recall to the reader's memory the extraordinary verification of a statement made about it more than a hundred years ago. We shall have for a moment to leave the paths of science for those of pure fiction, for the words we are going to quote are those of no less a person than our old friend Captain Gulliver, who, after his adventures with the Lilliputians, went to a flying island inhabited largely by astronomers. If the reader will take down his copy of Swift, he will find in this voyage of Gulliver's to Laputa the following imaginary description of what its imaginary astronomers saw:

"They have likewise discovered two lesser stars or satellites which revolve about Mars, whereof the innermost is distant from the center of the primary planet exactly three of its diameters, and the outermost five; the former revolves in the space of ten hours, and the latter in twenty-one and a half."

Now compare this passage, which was published in the year 1727, with the announcement in the scientific journals of August, 1877 (a hundred and fifty years after), that two moons did exist, and had just been discovered by Professor Hall, of Washington, with the great telescope of which a drawing has been already given. The resemblance does not end even here, for Swift was right also in describing them as very near the planet and with very short periods, the actual distances being about one and a half and seven diameters, and the actual times about eight and thirty hours respectively, distances and periods which, if not exactly those of Swift's description, agree with it in being less than any before known in the solar system. It is certain that there could not have been the smallest ground for a suspicion of their existence when "Gulliver's Travels" was written, and the coincidence — which is a pure coincidence — certainly approaches the miraculous. We can no longer, then, properly speak of "the snowy poles of moonless Mars," though it does still remain moonless to all but the most powerful telescopes in the world, for these bodies are the very smallest known in the system. They present no visible disks to measure, but look like the faintest of points of light, and their size is only to be guessed at from their brightness. Professor Pickering has carried on an interesting investigation of them. His method depended in part on getting holes of such smallness made in a plate of metal that the light coming through them would be comparable with that of the Martial moons in the telescope. It was found almost impossible to command the skill to make these holes small enough, though one of the artists employed had already distinguished himself by drilling a hole through a fine cambric needle *lengthwise*, so as to make a tiny steel tube of it. When the difficulty was at last overcome, the satellites were found to be less than ten miles in diameter, and a just impression both of their apparent size and light may be gathered from the statement that either roughly corresponds to that which would be given by a human hand held up at Washington, and viewed from Boston, Massachusetts, a distance of four hundred miles.

We approach now the only planet in which man is certainly known to exist, and which ought to have an interest for us superior to any which we have yet seen, for it is our own. We are voyagers on it through space, it has been said, as passengers on a ship, and many of us have never thought of any part of the vessel but the cabin where we are quartered. Some curious passengers (and these are the geographers) have visited the steerage, and some have looked into the hold, and yet it remains true that those in one part of our vessel know little, even now, of their fellow-voyagers in another. How much less, then, do most of us know of the ship itself, for we were all born on it, and have never once been off it to view it from the outside.

No world comes so near us in the aërial ocean as the moon; and if we desire to view our own earth as a planet, we may put ourselves in imagination in the place of a lunar observer. "Is it inhabited?" would probably be one of the first questions which he would ask, if he had the same interest in us that we have in him; and the answer to this would call out all the powers of the best telescopes such as we possess.

An old author, Fontenelle, has given us a lively picture of what might be visible in twenty-four hours if we could look down on the earth as it turned round beneath us. "I see passing under my eyes," he says, "all sorts of faces: white and black and olive and brown. Now it's hats and now turbans, now long locks and then shaven crowns; now come cities with steeples, next more with tall, crescent-capped minarets, then others with porcelain towers; now great desolate lands, now great oceans, then dreadful deserts,—in short, all the infinite variety the earth's surface bears." The truth is, however, that, looking at the earth from the moon, the largest moving animal, the whale or the elephant, would be utterly beyond our ken; and it is questionable whether the largest ship on the ocean would be visible, for the popular idea as to the magnifying power of great telescopes is exaggerated. It is probable that under any but extraordinary circumstances our lunar observer with our best telescopes could not bring the earth within less than an apparent distance of five hundred miles; and the reader may judge how large a moving object must be to be seen, much less recognized, by the naked eye at such a distance.

Of course, a chief interest of the supposition we are making lies in the fact that it will give us a measure of our own ability to discover evidences of life in the moon, if there are any such as exist here; and in this point of view it is worth while to repeat that scarcely any temporary phenomenon due to human action could be visible from the moon under the most favoring circumstances. An army such as Napoleon led to Russia might conceivably be visible if it moved in a dark solid column across the snow. It is barely possible that such a vessel as one of the largest ocean steamships might be seen, under very favorable circumstances, as a moving dot; and it is even quite probable that such a conflagration as the great fire of Chicago would be visible in the lunar telescope, as something like a reddish star on the night side of our planet; but this is all in this sort that could be discerned.

By making minute maps, or, still better, photographs, and comparing one year with another, much however might have been done by our lunar observer during this century. In its beginning, in comparison to the vast forests which then covered the North American continent, the cultivated fields along its eastern seaboard would have looked to him like a golden fringe bordering a broad mantle of green; but now he would see that the golden fringe has pushed aside the green farther back than the Mississippi, and would gather his best evidence from the fact (surely a noteworthy one) that man, as represented by the people of the United States, has changed one of the features of his world during the present century to a degree visible in another planet!

Our observer would probably be struck by the moving panorama of forests, lakes, continents, islands, and oceans, successively gliding through the field of view of his telescope as the earth revolved; but, traveling along beside it on his lunar station, he would hardly appreciate its actual flight through space, which is an easy thing to describe in figures, and a hard one to conceive. If we look up at the clock, and as we watch the pendulum recall that we have moved about nineteen miles at every beat, or in less than three minutes over a distance greater than that which divides New York from Liverpool, we still probably but very imperfectly realize the fact that (dropping all metaphor) the earth is really a great projectile, heavier than the heaviest of her surface rocks, and traversing space with a velocity of over sixty times that of the cannon-ball. Even the firing of a great gun with a ball weighing one or two hundred pounds is, to the novice at least, a striking spectacle. The massive iron sphere is hoisted into the gun, the discharge comes, the ground trembles, and, as it seems, almost in the same instant, a jet rises where the ball has just touched the water far away. The impression of immense velocity and of a resistless capacity of destruction in that flying mass is irresistible, and justifiable too; but what is this ball to that of the earth, which is a globe counting eight thousand miles in diameter, and weighing about six thousand millions of millions of millions of tons, which, if our cannon-ball were flying ahead a mile in advance of its track, would overtake it in less than the tenth part of a second, and which carries such a potency of latent destruction and death in this motion, that if it were possible to instantly arrest it, then, in that instant, "earth and all which it inherits would dissolve" and pass away in vapor?

Our turning sphere is moving through what seems to be all but an infinite void, peopled only by wandering meteorites, and where warmth from any other source than the sun can scarcely be said to exist; for it is important to observe that, whether the interior be molten or not, we get next to no heat from it. The cold of outer space can only be estimated in view of recent observations as at least four hundred degrees Fahrenheit below zero (mercury freezes at thirty-nine degrees below), and it is the sun which makes up the difference of all these lacking hundreds of degrees to us, but indirectly, and not in the way that we might naturally think, and have till very lately thought; for our atmosphere has a great deal more to do with it than the direct solar rays, allowing more to come in than go out, until the temperature rises very much higher than it would were there no air here. The writer's own experiments lead him to believe that the direct solar rays would never raise the temperature of the planet's surface, if that be entirely airless (even at the equator under the vertical beams of a tropic sun), to zero. Thus, since it is this power in the atmosphere of storing the heat which makes us live, no less than the sun's rays themselves, we see how the temperature of a planet may depend on considerations quite beside its distance from the sun; and when we discuss the possibility of life in other worlds, we shall do well to remember that Saturn may be possibly a warm world, and Mercury conceivably a cold one.

We used to be told that this atmosphere extended forty-five miles above us, but later observation proves its existence at a height of many times this; and a remarkable speculation, which Doctor Hunt strengthens with the great name of Newton, even contemplates it as extending in ever-increasing tenuity until it touches and merges in the atmosphere of other worlds.

But if we begin to talk of things new and old which interest us in our earth as a planet, it is hard to make an end. Still we may observe that it is the very familiarity of some of these which hinders us from seeing them as the wonders they really are. How has this familiarity, for instance, made commonplace to us not only the wonderful fact that the fields and forests, and the apparently endless plain of earth and ocean, are really parts of a great globe which is turning round (for this daily rotation we all are familiar with), but the less appreciated miracle that we are all being hurled through space with an immensely greater speed than that of the rotation itself. It needs the vision of a poet to see this daily miracle with new eyes, and a great poet has described it for us, in words which may vivify our scientific conception. Let us recall the prologue to "Faust," where the archangels are praising the works of the Lord, and looking at the earth, not as we see it, but down on it, from heaven, as it passes by, and notice that it is precisely this miraculous swiftness, so insensible to us, which calls out an angel's wonder.

"And swift and swift beyond conceiving
The splendor of the world goes round,
Day's Eden—brightness still relieving
The awful Night's intense profound.
The ocean tides in foam are breaking,
Against the rocks' deep bases hurled,
And both, the spheric race partaking,
Eternal, swift, are onward whirled."*

So, indeed, might an angel see it and describe it!

We may have been already led to infer that there is a kind of evolution in the planets' life, which we may compare, by a not wholly fanciful analogy, to ours; for we have seen worlds growing into conditions which may fit them for habitability, and again other worlds where we may surmise, or may know, that life has come. To learn of at least one which has completed the analogy, by passing beyond this term to that where all life has ceased, we need only look on the moon.

THE study of the moon's surface has been continued now from the time of Galileo, and of late years a whole class of competent observers has been devoted to it, so that astronomers engaged in other branches have oftener looked on this as a field for occasional hours of recreation with the telescope than made it a constant study. I can recall one or two such hours in earlier observing days, when, seated alone under the overarching iron dome, the world below shut out, and the world above opened, the silence disturbed by no sound but the beating of the equatorial clock, and the great telescope itself directed to some hill or valley of the moon, I have been so lost in gazing that it seemed as though a look through this, the real magic tube, had indeed transported me to the surface of that strange alien world. Fortunately for us, the same spectacle has impressed others with more time to devote to it and more ability to render it, so that we not only have most elaborate maps of the moon for the professional astronomer, but abundance of paintings, drawings, and models, which reproduce the appearance of its surface as seen in powerful telescopes. None of the latter class deserves more attention than the beautiful studies of Messrs. Nasmyth and Carpenter, who prepared at great labor very elaborate and, in general, very faithful models of parts of its surface, and then had them photographed under the same illumination which fell on the original; and I wish to acknowledge here the special indebtedness of this part of what I have to lay before the reader to their work, from which the following illustrations are chiefly taken.

Let us remember that the moon is a little over twenty-one hundred miles in diameter; that it weighs, bulk for bulk, about two-thirds what the earth does, so that, in consequence of this and its smaller size, its total weight is only about one-eightieth of that of our globe; and that, the force of gravity at its surface being only one-sixth what it is here, eruptive explosions can send their products higher than in our volcanoes. Its area is between four and five times that of the United States, and its average distance is a little less than two hundred and forty thousand miles.

This is very little in comparison with the great spaces we have been traversing in imagination; but it is absolutely very large, and across it the valleys and mountains of this our nearest neighbor disappear and present to the naked eye only the vague lights and shades known to us from childhood as "the man in the moon," and which were the puzzle of the ancient philosophers, who often explained them as reflections of the earth itself, sent back to us from the moon as from a mirror.

* Bayard Taylor's translation.

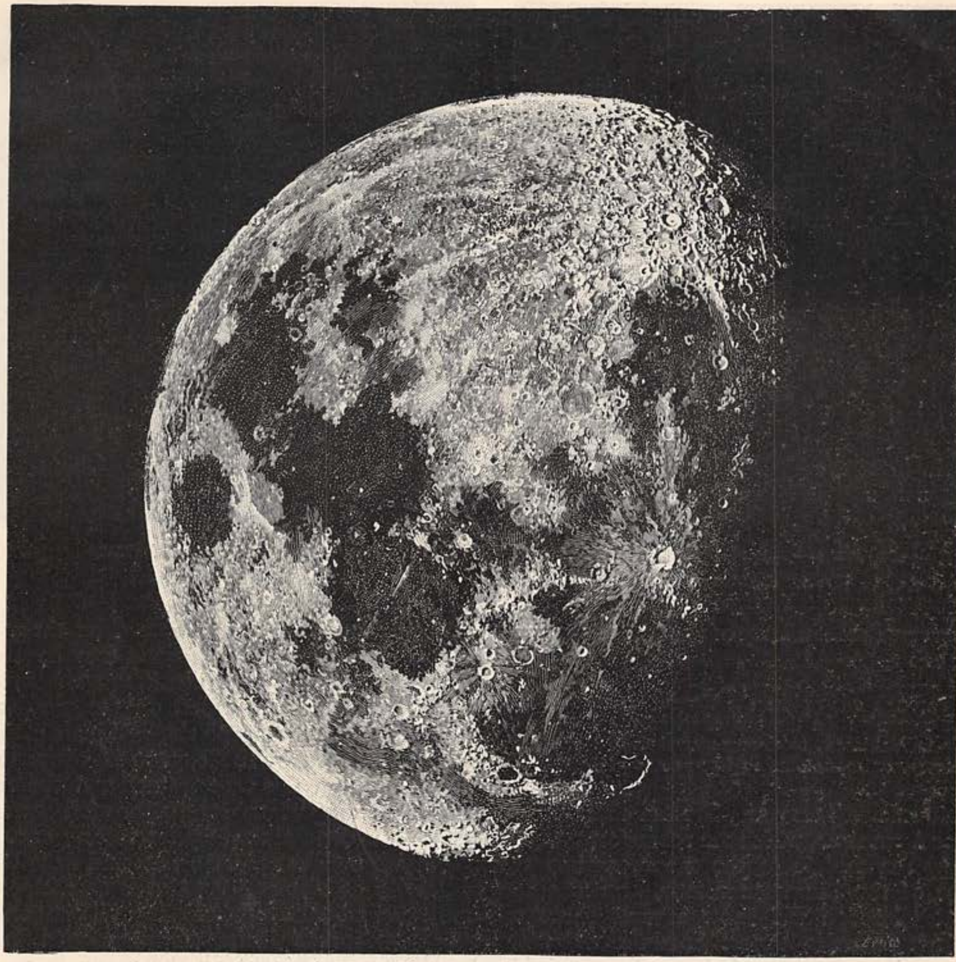

FIG. 6.—THE MOON. (FROM A PHOTOGRAPH BY L. M. RUTHERFURD, 1873, PUBLISHED BY O. G. MASON.)

It at any rate shows that the moon always turns the same face toward us, since we always see the same "man," and that there must be a back to the moon which we never behold at all; and, in fact, nearly half of this planet does remain forever hidden from human observation.

The "man in the moon" disappears when we are looking in a telescope, because we are then brought so near to details that the general features are lost; but he can be seen in any photograph of the full moon by viewing it at a sufficient distance, and making allowance for the fact that the contrasts of light and shade appear stronger in the photograph than they are in reality. If the small full moon given in Fig. 7, for instance, be looked at from across a room, the naked-eye view will be recovered, and its connection with the telescopic ones better made out. The best time for viewing the moon, however, is not at the full, but at the close of the first quarter; for then we see, as in this beautiful photograph (Fig. 6) by Mr. Rutherfurd (reduced by Mason), that the sunlight, falling slantingly on it, casts shadows which bring out all the details so that we can distinguish many of them even here — this photograph, though much reduced, giving the reader a better view than Galileo obtained with his most powerful telescope. The large gray expanse in the lower part is the Mare Serenitatis, that on the left the Mare Crisium, and so on; these "seas," as they were called by the old observers, being no seas at all in reality, but extended plains which reflect less light than other portions, and which with higher powers show an irregular surface. Most of the names of the main features of the lunar surface were bestowed by the earlier

FIG. 7.—THE FULL MOON.

FIG. 8.—GLASS GLOBE, CRACKED.

[From "The Moon," by Nasmyth and Carpenter. London: John Murray. By permission.]

observers in the infancy of the telescope, when her orb

"Through optic glass the Tuscan artist 'viewed'
At evening from the top of Fiesole
Or in Valdarno, to descry new lands,
Rivers, or mountains in her spotty globe."

Mountains there are, like the chain of the lunar Apennines, which the reader sees a little below the middle of the moon, and to the right of the Mare Serenitatis, and where a good telescope will show several thousand distinct summits. Apart from the mountain chains, however, the whole surface is visibly pitted with shallow, crater-like cavities, which vary from over a hundred miles in diameter to a few hundred yards or less, and which, we shall see later, are smaller sunken plains walled about with mountains or hills.

One of the most remarkable of these is Tycho, here seen on the photograph of the full moon (Fig. 7), from which radiating streaks go in all directions over the lunar surface. These streaks are a feature peculiar to the moon (at least we know of nothing to which they can be compared on the earth), for they run through mountain and valley for hundreds of miles without any apparent reference to the obstacles in their way, and it is clear that the cause is a deep-seated one. This cause is believed by our authors to be the fact that the moon was once a liquid sphere over which a hard crust formed, and that in subsequent time the expansion of the interior before solidification cracked the shell as we see. The annexed figure (Fig. 8) is furnished by them to illustrate their theory, and to show the effects of what they believe to be an analogous experiment, *in minimis*, to what nature has performed on the grandest scale; for the photograph shows a glass globe actually cracked by the expansion of an inclosed fluid (in this case water), and the resemblance of the model to the full moon beside it is certainly a very interesting one.

We are able to see from this, and from the multitude of craters shown even on the general view, where the whole face of our satellite is pit-marked, that eruptive action has been more prominent on the moon in ages past than on our own planet, and we are partly prepared for what we see when we begin to study it in detail.

We may select almost any part of the moon's surface for this nearer view, with the certainty of finding something interesting. Let us choose, for instance, on the photograph of the half-full moon (Fig. 6), the point near the lower part of the Terminator (as the line dividing light from darkness is called) where a minute sickle of light seems to invade the darkness, and let us apply in imagination the power of a large telescope to it. We are brought at once considerably within a thousand miles of the surface, over which we seem to be suspended, everything lying directly beneath us as in a bird's-eye view, and what we see is the remarkable scene shown in Fig. 9.

We have here such a wealth of detail that the only trouble is to choose what to speak of where every point has something to demand attention, and we can only give here the briefest reference to the principal features. The most prominent of these is the great crater "Plato," which lies in the lower right-hand part of the cut. It will give the reader an idea of the scale of things to state that the diameter of its ring is about seventy miles, so that he will readily understand that the mountains surrounding it may average five to six thousand feet in height, as they do. The sun is shining from the left, and, being low, casts long shadows, so that the real forms of the mountains on one side are beautifully indicated by these shadows, where they fall on the floor of the crater. In the lower part of the mountain wall there has been a landslide, as we see by the fragments that have rolled down into the plain, and of which a trace can be observed in our engraving. The whole is quite unlike most terrestrial craters, however, not only in its enormous size, but in its proportions; for the floor is not precipitous, but flat, or partaking of the general curvature of the lunar surface, which it sinks but little below. I have watched with interest in the telescope streaks and shades on the floor of Plato, not shown in our cut; for here some have suspected evidences of change, and fancied a faint greenish tint, as if due to vegetation, but it is probably fancy only. Notice the number of small craters around the big one, and everywhere on the plate, and then look at the amazingly rugged and tumbled mountain heaps on the left (the lunar Alps), cut directly through by a great valley (the valley of the Alps), which is at the bottom about six miles wide and extraordinarily flat — flatter and smoother even than our engraving shows it, and looking as though a great engineering work, rather than an operation of nature, were in question. Above this the mountain shadows are cast upon a wide plain, in which are both depressed pits with little

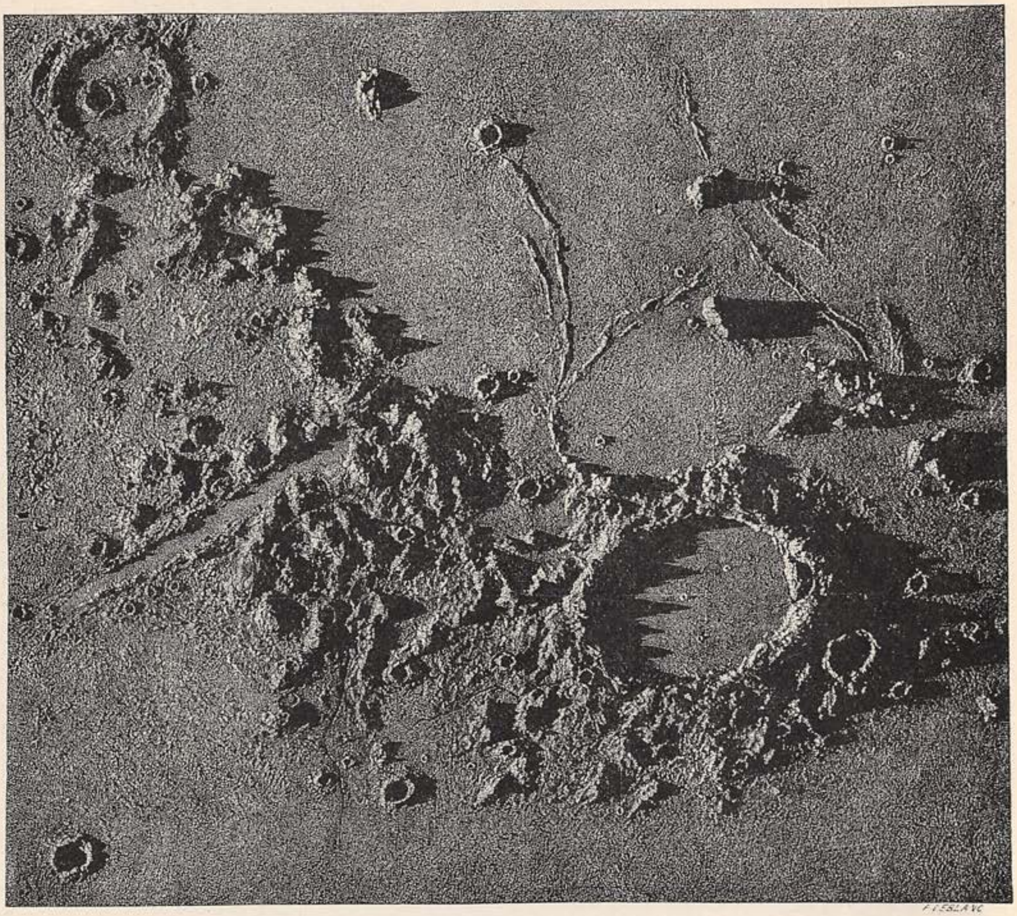

FIG 9.—PLATO AND THE LUNAR ALPS.

[From "The Moon," by Nasmyth and Carpenter. London: John Murray. By permission.]

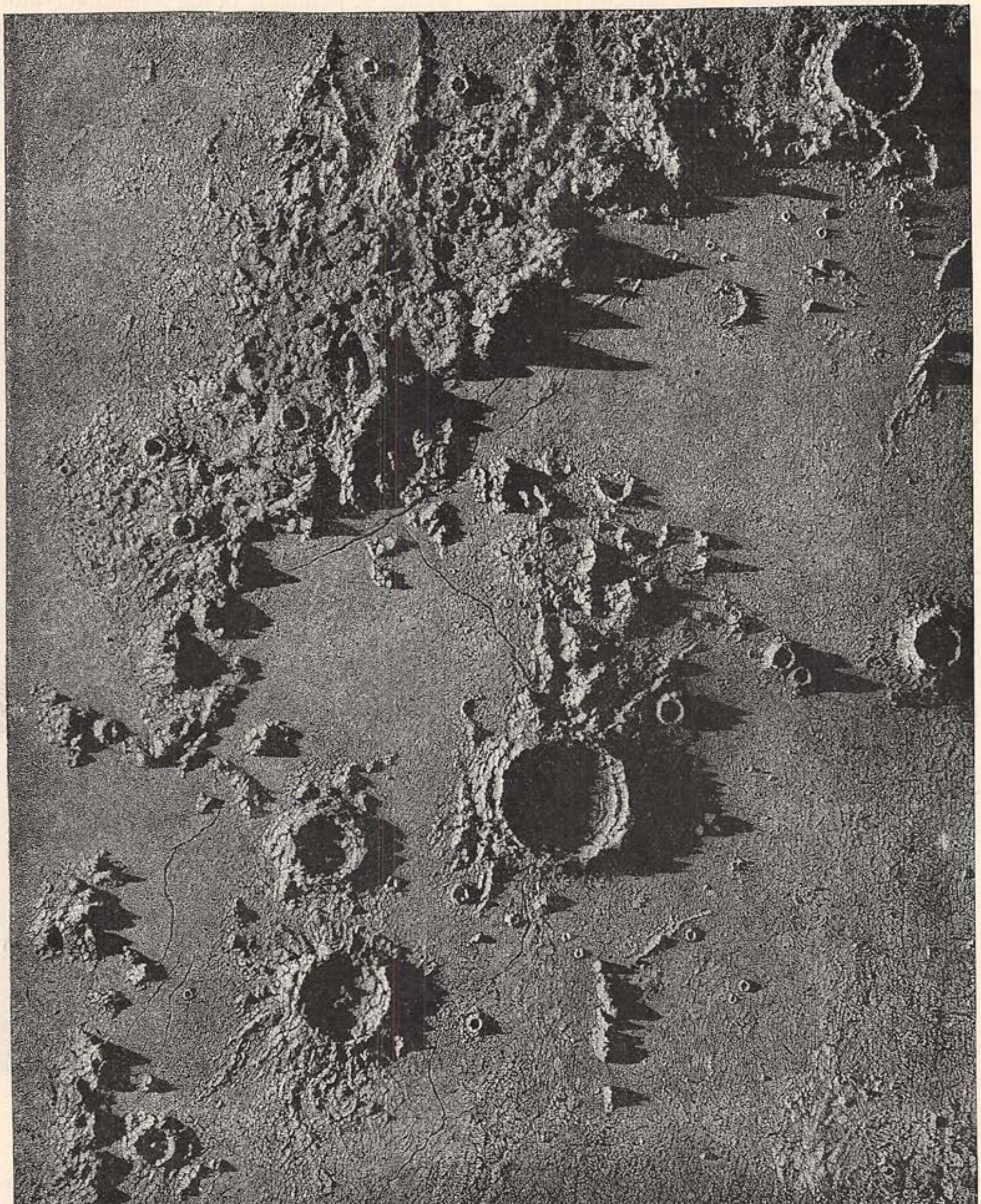

FIG. 10.—THE LUNAR APENNINES: ARCHIMEDES.

[From "The Moon," by Nasmyth and Carpenter. London: John Murray. By permission.]

mountain (or rather hill) rings about them, and extraordinary peaks, one of which, Pico (above the great crater), starts up abruptly to the height of eight thousand feet, a lunar Matterhorn.

If Mars were as near as the moon, we should see with the naked eye clouds passing over its face; and that we never do see these on the moon, even with the telescope, is itself a proof that none exist there. Now, this absence of clouds, or indeed of any evidence of moisture, is confirmed by every one of the nearer views like those we are here getting. We might return to this region with the telescope every month of our lives without finding one indication of vapor, of moisture, or even of air; and from a summit like Pico, could we ascend it, we should look out on a

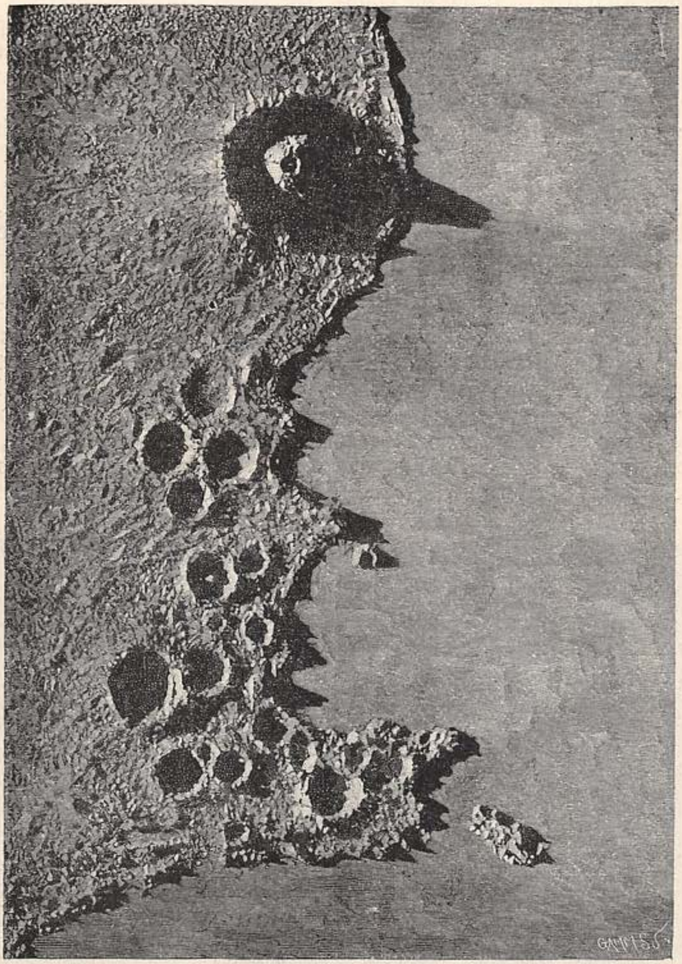

FIG. 11.—VESUVIUS AND NEIGHBORHOOD OF NAPLES.

[From "The Moon," by Nasmyth and Carpenter. London: John Murray. By permission.]

scene of such absolute desolation as probably no earthly view could parallel. If, as is conceivable, these plains were once covered with verdure, and the abode of living creatures, verdure and life exist here no longer, and over all must be the silence of universal death. But we must leave it for another scene.

South of Plato extends for many hundred miles a great plain, which from its smoothness was thought by the ancient observers to be water, and was named by them the "Imbrian Sea," and this is bounded on the south and west by a range of mountains—the "lunar Apennines" (Fig. 10)—which are the most striking on our satellite. They are visible even with a spy-glass, looking then like bread-crumbs ranged upon a cloth, while with a greater power they grow larger and at the same time more chaotic. As we approach nearer, we see that they rise with a comparatively gradual slope, to fall abruptly, in a chain of precipices that may well be called tremendous, down to the plain below, across which their shadows are cast. Near their bases are some great craters of a somewhat different type from Plato, and our illustration represents an enlarged view of a part of this Apennine chain, of the great crater Archimedes, and of its companions Aristillus and Autolycus.

Our engraving will tell, more than any description, of the contrast of the tumbled mountain peaks with the level plain from which they spring, a contrast for which we have scarcely a terrestrial parallel, though the rise of the Alps from the plains of Lombardy may suggest an inadequate one. The Sierra Nevadas of California climb slowly up from the coast side, to descend in great precipices on the east, somewhat like this; but the country at their feet is irregular and broken, and their highest summits do not equal those before us, which rise to 17,000 or 18,000 feet, and from one of which we should look out over such a scene of desolation as we can only imperfectly picture to ourselves from any experience of a terrestrial desert. The curvature of the moon's surface is so much greater than ours, that it would hide the spurs of hills which buttress the southern slopes of Archimedes, leaving only the walls of the great mountain ring visible in the extremest horizon, while between us and them would extend what some still maintain to have been the bed of an ancient lunar ocean, though assuredly no water exists there now.

Among the many fanciful theories to account for the forms of the ringed plains, one (and this is from a man of science whose ideas are always original) invokes the presence of water. According to it, these great plains were once ocean beds, and in them worked a coral insect, building up lunar "atolls" and ring-shaped submarine mountains, as the coral polyp does here. The highest summits of the great rings thus formed were then low islands, just "awash" with the waves of the ancient lunar sea, and, for aught we know, green with feathery palms. Then came (in the supposition in question) a time when the ocean dried up, and the mountains were left standing, as we see, in rings, after the cause of their formation was gone. If it be asked where the water went to, the answer is not very obvious on the old theories; but those who believe in them point to the extraordinary cracks in the soil, like those our engraving shows, as chasms and rents, by which the vanished seas, and perhaps also the

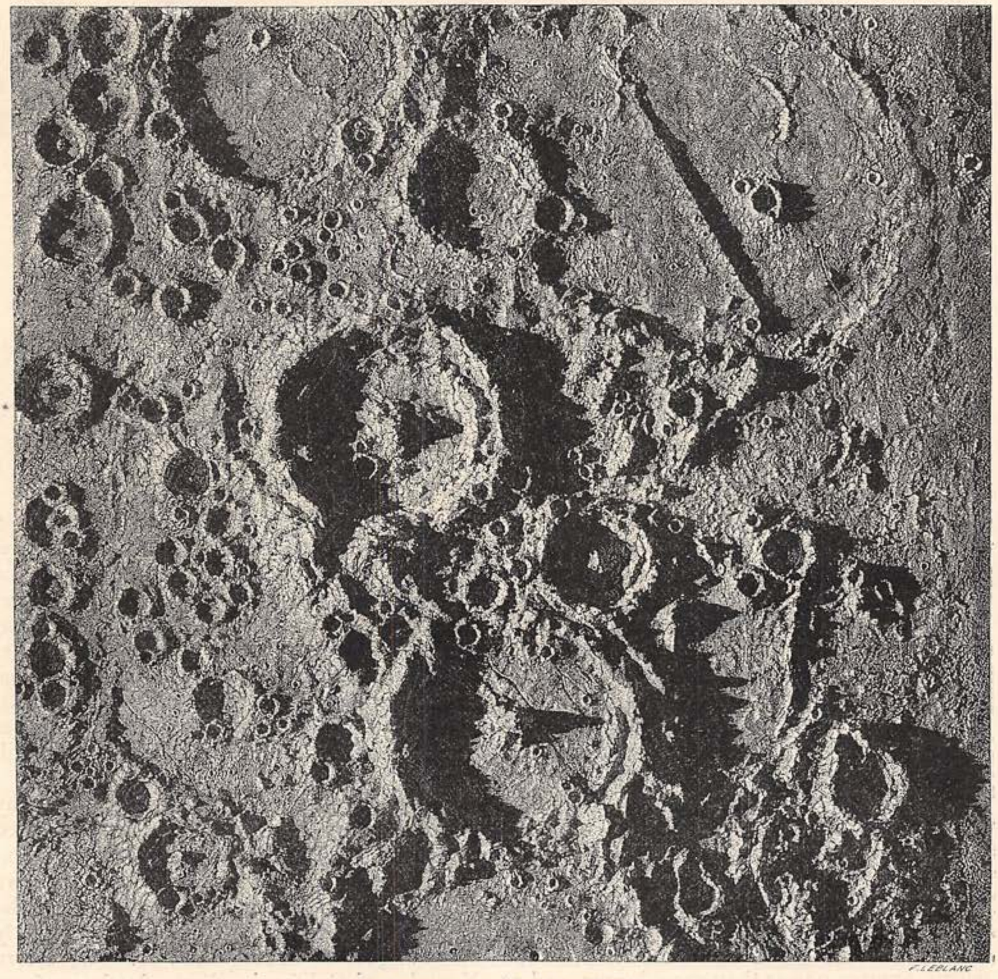

FIG. 12.—PTOLEMY AND ARZACHAEL.
[From "The Moon," by Nasmyth and Carpenter. London: John Murray. By permission.]

FIG. 13.—MERCATOR AND CAMPANUS.

[From "The Moon," by Nasmyth and Carpenter. London: John Murray. By permission.]

vanished air, have been absorbed into the interior.

If there was indeed such an ancient ocean, it would have washed the very feet of the precipices on whose summits we are in imagination standing, and below us their recesses would have formed harbors, which fancy might fill with commerce, and cities in which we might picture life and movement where all is now dead. It need hardly be said that no telescope has ever revealed their existence (if such ruins, indeed, there are), and it may be added that the opinion of geologists is, as a whole, unfavorable to the presence of water on the moon, even in the past, from the absence of any clear evidence of erosive action; but perhaps we are not yet entitled to speak on these points with certainty, and are not forbidden to believe that water may have existed here in the past by any absolute testimony to the contrary. The views of those who hold the larger portion of the lunar craters to have been volcanic in their formation are far more probable; and perhaps as simple an evidence of the presumption in their favor as we can give is directly to compare such a lunar region as this, the picture of which was made for us from a model, with a similar model made from some terrestrial volcanic region. Here (Fig. 11) is a photograph of such a modeled plan of the country round the Bay of Naples, showing the ancient crater of Vesuvius and its central cone, with other above the center of the full moon, and may be recognized also on the Rutherfurd photograph, and it consists of the group of great ring-plains, three of which form prominent figures in our cut.

Ptolemy (the lower of these in the drawing) is an example of such a plain, whose diameter reaches to about one hundred and fifteen miles, so that it incloses an area of nearly eight thousand square miles (or about that of the State of Massachusetts), within

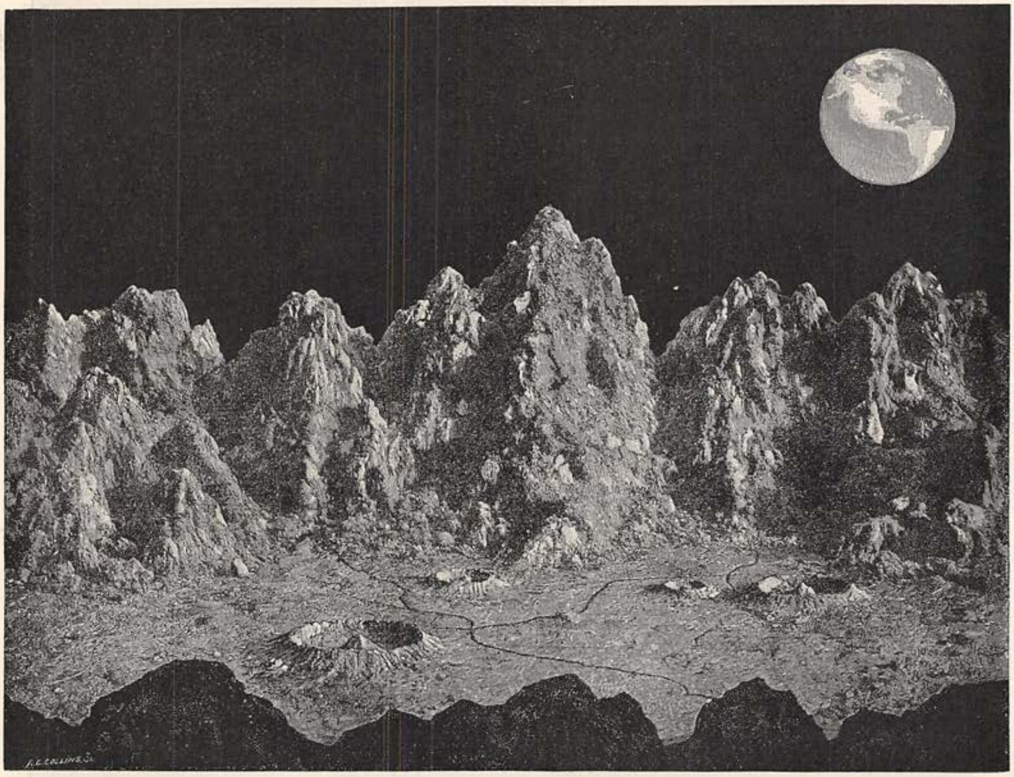

FIG. 14.—IDEAL LUNAR LANDSCAPE AND EARTH-SHINE.

[From "The Moon," by Nasmyth and Carpenter. London: John Murray. By permission.]

and smaller craters along the sea. Here, of course, we *know* that the forms originated in volcanic action, and a comparison of them with our moon-drawing is most interesting. To return to our Apennine region (Fig. 10), we must admit, however, when we consider the vast size of these things (Archimedes is fifty miles in diameter), that they are very different in proportion from our terrestrial craters, and that numbers of them present no central cone whatever; so that if some of them seem clearly eruptive, there are others to which we have great difficulties in making these volcanic theories apply. Let us look, for instance, at still another region (Fig. 12). It lies rather which there is no central cone or point from which eruptive forces appear to have acted, except the smaller craters it incloses. On the south we see a pass in the mountain wall opening into the neighboring ring-plain of Alphonsus, which is only less in size; and south of this again is Arzachel, sixty-six miles in diameter, surrounded with terraced walls, rising in one place to a height greater than that of Mont Blanc, while the central cone is far lower. The whole of the region round about, though not the roughest on the moon, is rough and broken in a way beyond any parallel here, and which may speak for itself; but perhaps the most striking of the many curious features — at least

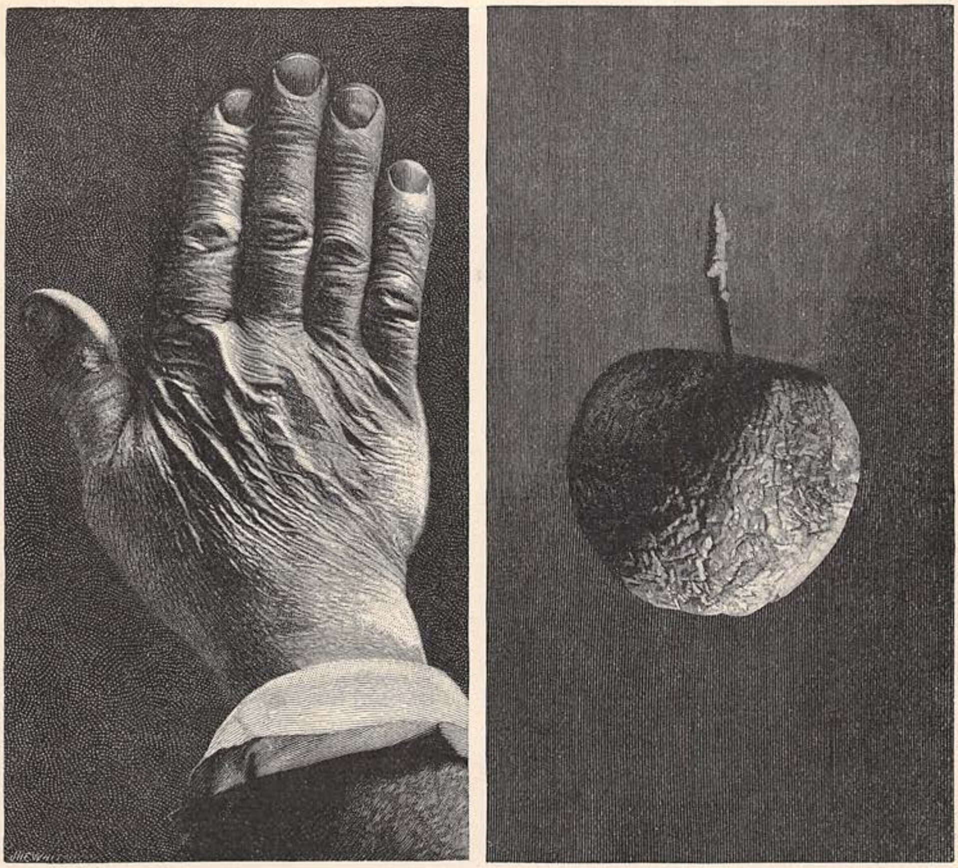

FIG. 15.—WITHERED HAND AND APPLE.
[From "The Moon," by Nasmyth and Carpenter. London: John Murray. By permission.]

the only one we can pause to examine—is what is called "The Railway," an almost perfectly straight line, on one side of which the ground has abruptly sunk, leaving the undisturbed part standing like a wall, and forming a "fault," as geologists call it. This is the most conspicuous example of its kind in the moon, but it is only one of many evidences that we are looking at a world whose geological history has been not wholly unlike our own. But the moon contains, as has been said, but the one-eightieth part of the mass of our globe, and has, therefore, cooled with much greater rapidity, so that it has not only gone through the epochs of our own past time, but has in all probability already undergone experiences which for us lie far in the future; and it is hardly less than justifiable language to say that we are beholding here in some respects what the face of our world may be when ages have passed away.

To see this more clearly, we may consider that in general we find that the early stages of cosmical life are characterized by great heat; a remark of the truth of which the sun itself furnishes the first and most obvious illustration. Then come periods which we appear to have seen exemplified in Jupiter, where the planet is surrounded by volumes of steam-like vapor, through which we may almost believe we recognize the dull glow of not yet extinguished fires; then times like those which our earth passed through before it became the abode of man; and then the times in which human history begins. But if this process of the gradual loss of heat go on indefinitely, we must yet come to still another era, when the planet has grown too cold to support life, as it was before too hot; and this condition, in the light of some very recent investigations, it seems probable we have now before us on the moon.

We have, it is true, been taught until very lately that the side of the moon turned sunward would grow hotter and hotter in the long lunar day, till it reached a temperature of two hundred to three hundred degrees

Fahrenheit, and that in the equally long lunar night it would fall as much as this below zero. But the evidence which was supposed to support this conclusion is not supported by recent experiments; and if these be trustworthy, certain facts appear to the writer to show that the temperature of the moon's surface, even under full perpetual sunshine, must be very low indeed,—lower than that of our arctic or antarctic poles,—and this because of the absence of air there to keep the stored sun-heat from being radiated away again into space.

As we ascend the highest terrestrial mountains, and get partly above our own protecting blanket of air, things do not grow hotter and hotter, but colder and colder; and it seems contrary to the teachings of common sense to believe that if we could ascend higher yet, where the air ceases altogether, we should not find that it grew colder still. But this last condition (of airlessness) is the one which does prevail beyond a doubt in the moon, on whose whole surface, then, there must be (unless there are sources of internal heat of which we know nothing) conditions of temperature which are an exaggeration of those we experience on the summit of a very lofty mountain, where water freezes under the full rays of a vertical sun; and we have the curious result that the skin may be burned under the solar rays, while we are shivering at the same time in what the thermometer shows is an arctic cold.

We have heard of this often, but a personal experience so impressed the fact on me that I will relate it for the benefit of the reader, who may wish to realize to himself the actual conditions which probably exist in the airless lunar mountains and plains we are looking at. He cannot go there, but he may go if he pleases, as I have done, to the waterless, shadeless desert which stretches at the eastern slope of the Sierra Nevadas (a chain almost as high and steep as the lunar Apennines), and live some part of July and August in this desert, where the thermometer rises occasionally to one hundred and ten degrees in the shade, and his face is tanned till it can tan no more, and he appears to himself to have experienced the utmost in this way that the sun can do.

The sky is cloudless, and the air so clear that all idea of the real distance and size of things is lost. The mountains, which rise in tremendous precipices above him, seem like moss-covered rocks close at hand, on the tops of which, here and there, a white cloth has been dropped, but the "moss" is great primeval forests, and the white cloths large isolated snow-fields, tantalizing the dweller in the burning desert with their delusive nearness. When I climbed the mountains, at an altitude of ten thousand feet I already found the coolness delicious, but at the same time (by the strange effect I have been speaking of) the skin began to burn, as though the seasoning in the desert counted for nothing at all; and as the air grew thinner and thinner while I mounted still higher and higher, though the thermometer fell, every part of the person exposed to the solar rays presented the appearance of a recent severe burn from an actual fire,—and a really severe burn it was, as I can testify,—and yet all the while around us, under this burning sun and cloudless sky, reigned a perpetual winter which made it hard to believe that torrid summer still lay below. The thinner the air, then, the colder it grows, even where we are exposed to the sun, and the lower becomes the reading of the thermometer. Now, by means of suitable apparatus, it was sought by the writer to determine, while at this elevation of fifteen thousand feet, *how* great the fall of temperature would be if the thin air there could be removed altogether; and the result was that the thermometer would under such circumstances fall, at any rate, below zero in the full sunshine.

Of course, all this applies directly to the moon, on whose surface (if these inferences be correct) the mercury in the bulb of a thermometer would probably freeze and never melt again during the lunar day (and still less during the lunar night)— a conclusion which has been reached through other means by Mr. Ericsson.

Other and direct measures of the lunar heat are still in progress while this is being written, but their probable result seems to be already indicated: it is that the moon's surface, even in perpetual sunshine, must be forever under a more than arctic cold — a cold below the freezing-point of mercury, and in which we cannot conceive of the existence of man or of organic life.

Here (Fig. 13) is one more scene from the almost unlimited field the lunar surface affords.

The most prominent things in the landscape before us are two fine craters (Mercator and Campanus), each over thirty miles in diameter; but we have chosen this scene for remark rather on account of the great crack or rift which is seen in the upper part, and which cuts through plain and mountain for a length of sixty miles. Such cracks are counted by hundreds on the moon, where they are to be seen almost everywhere; and other varieties, in fact, are visible on this same plate, but we will not stop to describe them. This one varies in width from an eighth of a mile to a mile; and though we cannot see to the bottom of it, others are known to be at least eight miles deep, and may be indefinitely deeper.

The edge of a cliff on the earth commonly gets weather-worn and rounded, but here the edge is sharp, so that a traveler along the lunar plains would come to the very brink of this tremendous chasm before he had any warning of its existence. It is usually thus with all such rifts, and the straightness and sharpness of the edge in these cases suggest the appearance of an ice-crack to the observer. I do not mean to assert that there is more than a superficial resemblance. I do not write as a geologist; but in view of what we have just been reading of the lunar cold, we may ask ourselves whether, if water ever did exist here, we should not expect to find perpetual ice, not necessarily glittering, but covered, perhaps, with the deposits of an air laden with the dust-products of later volcanic eruptions, or even covered in after ages, when the air has ceased from the moon, with the slow deposit of meteoric dust during millions of years of windless calm. What else can we think will become of the water on our own earth if it be destined to pass through such an experience as we seem to see prophesied in the condition of our dead satellite?

The reader must not understand me as saying that there is ice on the moon — only that there is probably perpetual ice there now *if* there ever was water in past time; and he is not to suppose that to say this is in any way to deny what seems the strong evidence of the existence of volcanic action everywhere, for the two things may well have existed in successive ages of our satellite's past, or even have both existed together, like Hecla, within our own arctic snows; and if no sign of any still active lunar volcano has been discovered, we appear to read the traces of their presence in the past none the less clearly.

I remember that at one time, when living on the lonely upper lava-wastes of Mt. Etna, which are pitted with little craters, I grew acquainted with so many a chasm and rent filled with these that the dreary landscape appeared from above as if a bit of the surface of the moon I looked up at through the telescope had been brought down beside me.

I remember, too, that as I studied the sun there and watched the volcanic outbursts on its surface, I felt that I possibly embraced in a threefold picture as many stages in the history of planetary existence, through all of which this eruptive action was an agent,— above in the primal energies of the sun, all around me in the great volcano, black and torn with the fires that still burn below, and whose smoke rose over me in the plume that floated high up from the central cone, and finally in this last stage in the moon, which hung there pale in the daylight sky, and across whose face the vapors of the great terrestrial volcano drifted, but on whose own surface the last fire was extinct.

We shall not get an adequate idea of it all, unless we add to our bird's-eye views one showing a chain of lunar mountains as they would appear to us if we saw them, as we do our own Alps or Apennines, from about their feet, and such a view Fig. 14 affords us. In the barren plain on the foreground are great rifts such as we have been looking at from above, and smaller craters, with their extinct cones; while beyond rise the mountains, ghastly white in the cold sunshine, their precipices crowned by no mountain fir or cedar, and softened by no intervening air to veil their nakedness.

If the reader has ever climbed one of the highest Alpine peaks, like those about Monte Rosa or the Matterhorn, and there waited for the dawn, he cannot but remember the sense of desolation and strangeness due to the utter absence of everything belonging to man or his works or his customary abode, above all which he is lifted into an upper world, so novel and, as it were, so unhuman in its features, that he is not likely to have forgotten his first impression of it; and this impression gives the nearest but still a feeble idea of what we see with the telescope in looking down on such a colorless scene, where, too, no water bubbles, no tree can sigh in the breeze, no bird can sing — the home of silence.

But here, above it, hangs a world in the sky, which we should need to call in color to depict, for it is green and yellow with the forests and the harvest-fields that overspread its continents, with emerald islands studding its gray oceans, over all of which sweep the clouds that bring the life-giving rain. It is our own world, which lights up the dreary lunar night, as the moon does ours.

The signs of age are on the moon. It seems pitted, torn, and rent by the past action of long-dead fires, till its surface is like a piece of porous cinder under the magnifying glass— a burnt-out cinder of a planet, which rolls through the void like a ruin of what has been; and, more significant still, this surface is wrinkled everywhere, till the analogy with an old and shriveled face or hand or fruit (Fig. 15), where the puckered skin is folded about a shrunken center, forces itself on our attention, and suggests a common cause — a something underlying the analogy, and making it more than a mere resemblance.

The moon, then, is dead; and if it ever was the home of a race like ours, that race is dead too. I have said that our new astronomy modifies our view of the moral universe

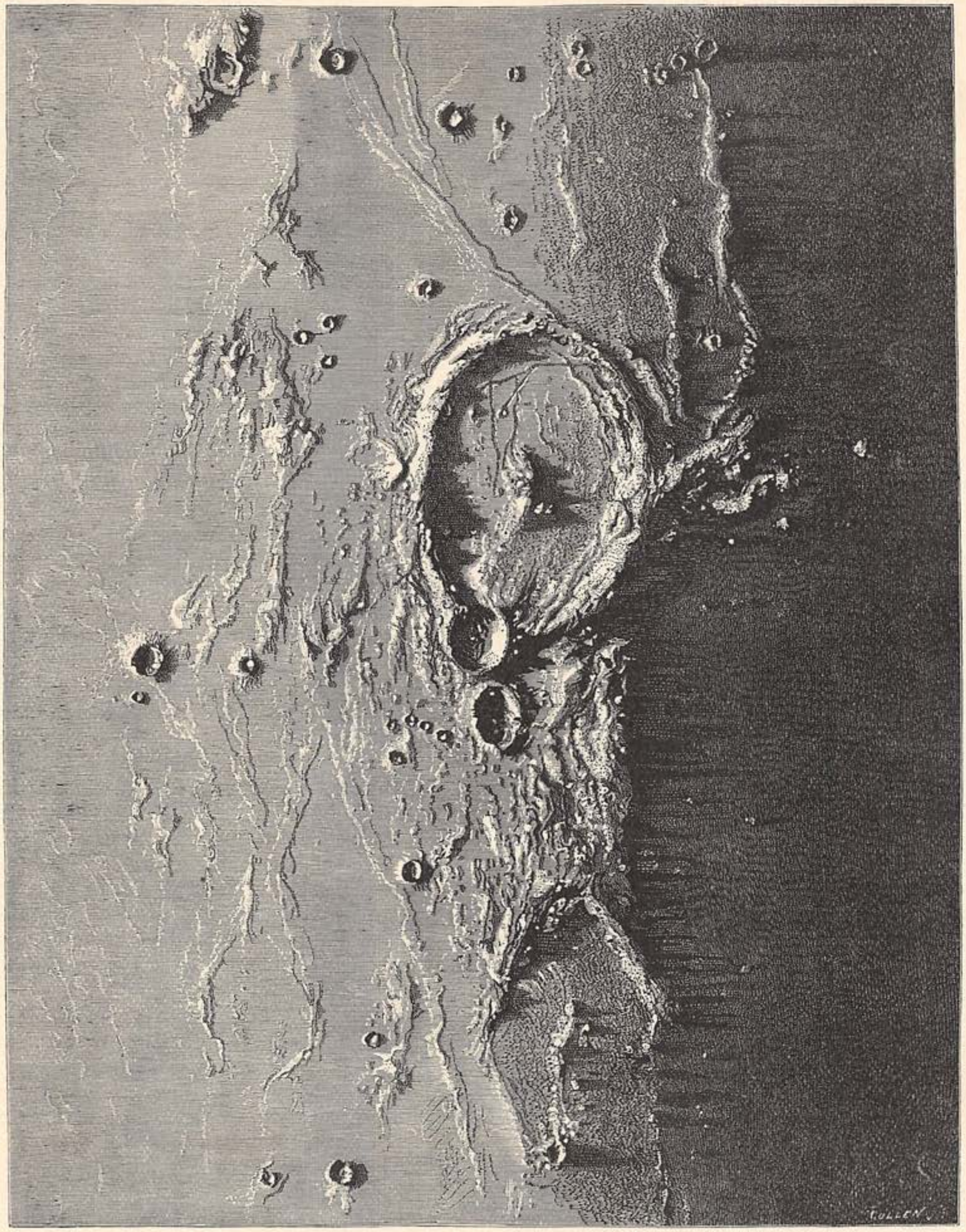

FIG. 16.—GASSENDI. NOVEMBER 7th, 1867.
[From "The Moon," by Nasmyth and Carpenter. London: John Murray. By permission.]

as well as of the physical one; nor do we need a more pregnant instance than in this before us. In these days of decay of old creeds of the eternal, it has been sought to satisfy man's yearning toward it by founding a new religion whose god is Humanity, and whose hope lies in the future existence of our own race, in whose collective being the individual who must die may fancy his aims and purpose perpetuated in an endless progress. But, alas for hopes looking to this alone! we are here brought to face the solemn thought that like the individual, though at a little further date, Humanity itself may die!

Before we leave this dead world, let us take a last glance at one of its fairest scenes: that which we obtain when looking at a portion on which the sun is rising, as in this view of

Gassendi (Fig. 16), in which the dark part on our right is still the body of the moon, on which the sun has not yet risen. Its nearly level rays stretch elsewhere over the surface, that is, in places of a strangely smooth texture, contrasting with the ruggedness of the ordinary soil, which is here gathered into low plaits, that, with the texture we have spoken of, look

> "Like marrowy crapes of China silk,
> Or wrinkled skin on scalded milk,"

as they lie, soft and almost beautiful, in the growing light.

Where its first beams are kindling, the summits cast their shadows illimitedly over the darkening plains away on the right, until they melt away into the night — a night which is not utterly black, for even here a subdued radiance comes from the earth-shine of our own world in the sky.

Let us leave here the desolation about us, happy that we can come back at will to that world, our own familiar dwelling, where the meadows are still green and the birds still sing, and where, better yet, still dwells our own kind — surely the world, of all we have found in our wanderings, which we should ourselves have chosen to be our home.

[END OF THE PRESENT SERIES.] *S. P. Langley.*

REMINISCENCES OF DANIEL WEBSTER.*

My acquaintance with Mr. Webster might almost be regarded as a family inheritance rather than a personal acquisition. It grew out of connections reaching as far back as the middle of the last century. Both my grandfathers, Japhet Allen and Jeremiah Gilman, were with Ebenezer Webster, the father of Daniel, in the revolutionary war, and Colonel David Gilman, my grandfather's brother, was with him in the old French and Indian wars under Washington and Amherst. My grandmother on my mother's side was a distant relative of the mother of Mr. Webster, and a native of her region; and her brother resided in the town of Boscawen during his life, and for many years was familiarly acquainted with all the Webster family. To enlarge this family association: my grandmother on my father's side was born on part of the Webster estate at Marshfield; and the old cellar of the house of her ancestors was well preserved during Mr. Webster's life: and many of her family are interred in the Pilgrim burying-ground, where the Webster tomb is situated. Both my father and Mr. Webster were born the same year, and while the latter taught at Fryeburg Mr. Allen presided over a district school in the country near by. They were companions on many a fishing and rambling excursion round Mount Chocorua and the tributaries of the Saco. Tradition has it that they both received instruction in Latin from the same preceptor, Rev. Samuel Hidden, of Tamworth, N. H. Thus I may fairly be said to have imbibed my love and admiration and knowledge of the great statesman with my mother's milk. My first sight of him was in a crowded courtroom of a country village in New Hampshire. It was more than half a century ago; and, though I was hardly ten years of age, I well remember how overawed I was at the introduction. My next acquaintance with his name was when he was engaged in the Salem Murder case as counsel for the Government against Knapp *et al.* But it was not until I came to Boston, a youth of seventeen summers, and was casually presented to him again, that I realized the greatness and felt the influence

* The portrait of Webster, printed as a frontispiece, is from a daguerreotype made by Mr. F. de B. Richards, of Philadelphia. Mr. Richards, now a painter, was formerly a daguerreotypist, and went, under the guidance of Dr. McClellan (father of the general), to get Webster to pose for the likeness. Mr. Richards is confident that this was in 1849, though we can find no record of a public speech made by Webster in Philadelphia in that year. Mr. Richards says that Webster had spoken with his hat on, and they wished to preserve a memento of the speech; but when they found Webster he was pacing the floor in furious anger, frowning like Jupiter Tonans, because some unfeeling creditor had ventured to dun him for a debt. Dr. McClellan whispered to Richards not to touch the picture question. Meantime, Webster's friends were raising money among the Whigs with which to satisfy the debt. At ten minutes before two the doctor and the daguerreotypist returned, to find the lion tame and happy. But there was to be a reception that afternoon, and Webster turned and growled, "McClellan, if that picture is to be taken, it must be at two o'clock." Dr. McClellan thereupon whispered to Richards to run and have all things ready. Mr. Richards remembers hearing Webster's angry grumbling when he reached the top of the third flight at finding he must mount one more. When he entered the gallery Richards said: "Stand just as you are, Mr. Webster; we wish to take you first with your hat on." "Your first will be your last," roared the statesman. But when the artist announced that the sitting was ended in about four seconds, he said: "What, all done?" "Yes." "Why, in Boston they will set your —— eyes out!" and he sat for two or three other pictures. The hat shown in the picture, or a similar one, is preserved in the "Historical" rooms in Philadelphia.— ED.