V E N U S.

I.

At first ~~blush~~ sight it may certainly seem strange that ~~hitherto~~ of all the heavenly bodies ~~the world should have hitherto have known~~ the one ~~the~~ hitherto the least known to the world should ~~hitherto~~ have been ~~about the one which is~~ her nearest neighbor, the planet Venus. When we consider that men have ~~been able to tell~~ succeeded in finding out the physical con-stitu~~tion~~ents of stars so distant that ~~even~~ light ~~in~~ with its amazing swift-ness ~~of 187000 miles a second~~ takes ~~decades and~~ centuries to bring the news; that they have been able to recognize the presence ~~to tell that~~ of such iron, magnesium and ~~other~~ the like familiar sub-stances as are present ~~there~~ in those far-off suns and to make very plausible inference as to the condition these same suns ~~stars~~ may be in, it is to say the least surprising that next to nothing should have been known of the body which ~~at times is~~, reckoned in light years, ~~only two minutes away and is never more than 2 minutes away and is~~ ~~even at its farthest~~ never more than 14 min tes off from us ~~and~~ at times but twice sixty seconds. Two minutes away from us. ~~If we compare knowledge of her with with knowledge~~ of the other planets we are struck by the same curious discrepancy. Of the condition of Jupiter much was known and more fairly in-ferable. Less but still a good deal was known of that of Saturn. While in the case of Mars our knowledge was greater than would have seemed possible. Yet Jupiter never comes within a twelfth part of the distance of us that Venus does and even Mars at his nearest is a third again as far off as is at times the planet named after the Goddess of Love. Yet in spite of nearness, in spite of suspected affinities greater than in the case of any

"You dared not see me because you dared not deny your innocence," she declared, with sudden vehemence. "You have not denied it. You cannot deny it. You can do all the rest, but you cannot look me in the eyes and lie. Thank God, your honor is spotless. Thank God, I always knew it."

He breathed deep; across his face flitted swift reflections of varying emotions, as if he fain would respond a thousand things to her sweet turbulence, yet he merely stooped and slowly kissed her hands, and said in his kind and simple way, "Little Erika was always a loyal little thing;" and in answer to her troubled gaze, "It is not really good-by. I shall always come to Azor. We will make him a strong man yet. Some time you will trust him to me. And you and I are always at heart the old" —

"Rascals!" she suggested, smiling with wet eyes.

"And we shall see each other now and then, if only to pass with a good thought and the memories that will always live. But Guido is dead. These marigolds grew on his grave. There is nothing at all gloomy about them. See how gay and sunny they look. Let us never mourn or resurrect him again. Now give Michel one good word before he goes."

"It is inconceivable, humiliating," she exclaimed, between a sob and a laugh, "but I am actually beginning to like Michel and his marsh-marigolds!"

"Always my generous little Erika, so straight and honest, so utterly her old self, so like Azor! Marigold-Michel thanks you from his heart that you could say that. It will help him in hours when he is not jingling his bells."

"Ah, such hours come!"

Again he bent over her hands. "Farewell, dear little duchess."

"Farewell — Michel," she faltered.

"Now smile, Serenissime; and ring and hand me over to the tender mercies of the calves."

"Show Marigold-Michel out," said her Grace languidly.

Turning away, she paid no further attention to the tall bright figure crossing the room, but bent over a bunch of yellow flowers lying on her writing-table.

Blanche Willis Howard.

VENUS IN THE LIGHT OF RECENT DISCOVERIES.

I.

At first sight, it may certainly seem strange that of all the heavenly bodies the one hitherto the least known to the world should have been her nearest neighbor, the planet Venus. When we consider that men have succeeded in finding out the physical constituents of stars so distant that light, with its amazing swiftness, takes centuries to bring the news; that they have been able to recognize the presence in those far-off suns of such familiar substances as iron, magnesium, and the like, and to make very plausible inference as to the condition those same suns may be in, it is surprising, to say the least, that next to nothing should have been known of the body which, reckoned in light years, is at times but two minutes away from us.

Nor does the wonder stop here. If we compare what we know of her with what we know of the other planets, instead of the stars, a like seemingly unaccountable discrepancy is patent. Of Jupiter we had learnt much, and could infer more; of Saturn, even, we knew something; while of Mars we had knowledge beyond what some people will believe. Yet Jupiter never approaches us within a fourteenth part of the distance that Venus does, and Mars at his nearest is a third farther away than is at times the beautiful body well named by the ancients after the Goddess of Love. But in spite of proximity, and as if in justification of her name, the planet of love remained as much of a mystery as love itself.

That we knew so little of one who is both our nearest neighbor and our next of kin was chargeable to a combination of causes. Chief of these is her position. So situated is the orbit of Venus with regard to the orbit of the earth as to put the planet always in a more or less unfavorable position for observation. This comes from the fact that she is what is called an inferior planet; that is, her orbit lies within that of the earth. Therefore, when nearest to us she lies between us and the sun ; and as the side toward the sun is the illuminated one, she then turns earthward her unillumined half. Although near us at the time, she might for all visual purposes be infinitely far off.

As a next untoward consequence of the relative position of her orbit, she appears to observers on earth never to depart far, even at her farthest, from the sun's neighborhood; contenting herself with oscillating, pendulum-wise, back and forth through a swing of 47° on either side of him. The result of this is that she is more or less hidden by his rays when the two are above the horizon together ; more or less obscured by horizon mists and tremors after he has set. Hence observers have a choice of evils : either to seek her through a sunlit sky, or to watch her low down against a twilight one. Nor is this the end of the list of difficulties with which observation of her is invested. In addition to being drenched in light, the day sky is usually in an atmospheric condition most ill adapted to astronomical research. Owing to the heating to which it is exposed, the day air is in anything but a steady state. The result of all these difficulties has been that until now the planet has showed to earthly observers nothing but a fair blond face devoid of any features more salient than shading here and there. To this absence of identifiable traits it is due that, with the single exception of our knowing that Venus had an atmosphere, — revealed by the aureole seen about her when in transit across the sun, — the planet, so far as we knew her, might have been but the particle of matter recognized by gravitational astronomy whose sole distinction is ponderosity.

What we did not know about the planet would take too long to tell, since, with the single exception of atmosphere, it was everything. The planet, indeed, was one of the enigmas of astronomy. We not only did not know what she was like; we did not even know what she was likely to be. For we lacked the basic facts to a solution of the question. We were ignorant of such essentials to any real knowledge of her as whether she had seasons, or even, fundamental point of all, whether she had a day.

That we should have been ignorant of this fundamental fact, her day, shows how absolute our nescience was ; for the possession or non-possession of a day is the most vital factor to the determination of a planet's condition. To the fact of having a day are due, so far as we can see, all the phenomena upon a planet's surface which we know as life. Without a day life could not exist. It is not only that no life of which we have cognizance could continue everlastingly awake. The objection to a lack of night on the score of insomnia is one which might be overruled by our learning to sleep by day, as many men already do professionally, and many others *en amateur*. It is that perpetual motion is as impossible to our machinery as to any other. The chain of changes we know as life depends upon general alternations in nature for its continuance. All growth, be it animal or vegetal, turns, for instance, for its possibility, upon a recurrent supply of water. According to its kind each plant must be furnished by nature with a sufficiency, and yet not an excess of it. Too much or too little is alike fatal. Now, the alternation of day and night produces a periodic cycle of meteorological change which makes rain possible. If there were no variation in the cause, there could be no variation in the effect. By a continuance in perpetuity of the same state of things a condition of equilibrium must eventually be brought about, in which all change would cease, and with the absence of change all life would become an impossibility.

The possession by a planet of a day depends upon how fast the planet turns on its own axis in the course of its yearly circuit about the sun. If it turn at any rate except one, it will have a day of greater or less duration; but if it turn at one special rate, it will have no day at all. This special rate is the rate at which its orbital revolution carries it around the sun. For if it turn upon its own axis just as fast as, and no faster than, it appears to turn in the reverse manner about the sun, in consequence of its circuit of that body, the one turning will offset the other, and relatively to the sun the planet will not seem to turn at all. It will present the same face to the sun in perpetuity. Eternal day will be the lot of one side of it, and eternal night the lot of the other. But of days, properly speaking, — that is, of the periodic alternations of light and darkness, — there will be none.

Next to the possession of a day comes the possession of seasons. A planet without seasons would be to us, although not an impossible place of abode, at least a singular one, — no spring, no summer, no autumn, no winter, anywhere; instead, an intemperately hot belt about the equator, intemperately cold ones round the poles, and, except for storms, temperately same regions between; and all in perpetuity.

Whether a planet have seasons or not depends upon the tilt of its axis to the plane of its orbit. If the axis be perpendicular to that plane, it will have none. If it be moderately inclined to the perpendicular, it will have them; while if it be immoderately inclined to it, a most curious jumble of the seasons will result: into this it is not necessary here to go.

And all this is but the beginning of the nescience which follows from our inability to make out the features of a planet's surface. Not to see them bears poignantly upon the water problem, for example, as well as upon all the other questions that naturally arise. But to pursue such nescience farther would be futile. It is more interesting to turn from what we did not know to what we have just learnt. To do this we may best begin with a short account of previous astronomical research in the case.

II.

Owing to the impossibility of making out any certain markings upon her disk, the physical condition of Venus, up to the present time, has been matter of speculation, and her rotation period matter of doubt. Study of her has been interesting, viewed negatively, for it has been singularly inconclusive.

Francesco Bianchini was the first to attempt the study of her surface with even the semblance of success. During the later twenties of the eighteenth century he made a series of observations in which he thought he saw some shadelike markings on the disk. From these he constructed a map, and deduced a rotation period of 24 days and about 8 hours. His map suggests a very early geologic age, being *informe, ingens, cui lumen ademptum.* It consists solely of four indefinite patches, darker than the rest of the disk. Two of these occupy the centre, one being a long oval and one more nearly round; the other two belt each pole respectively. In 1779 the indefatigable Schroeter came to the conclusion that the rotation period was something quite different, namely, 23 hours, 21 minutes, and 19 seconds. In 1809, from phenomena observed by him about the southern horn of the planet, he deduced with still more marvelously minute inaccuracy, as it has turned out, the period of 23 hours, 21 minutes, 9.977 seconds. In 1842 De Vico attacked the question at Rome. He and his assistants made a very great number of observations, taking some eleven thousand measurements in all. In the course of these they recovered all Bianchini's spots, added a new one, and deduced for the rotation period the value 23 hours, 21 minutes, 21.9345 seconds, a superb superstructure on, unfortunately, an insecure basis.

Practically nothing more was done until quite recently, when several observers took up the matter again, notably Schiaparelli, whose insight — as well as eyesight — made him the first to suspect and to render highly probable a period very different from anything approaching twenty-four hours. The history of the subject up to 1893 is thus summed up by Stanley Williams in the last edition of Webb, published in that year: —

"The question of the duration of the rotation of Venus is still a disputed one, and several very elaborate though contradictory investigations upon the subject have been published within the last few years. In 1890 Schiaparelli came to the conclusion, after a very exhaustive discussion of all the existing material, including some observations of his own, that the rotation of Venus is very slow; and that whilst being very probably equal to the time taken by the planet in making one revolution round the sun (225 days), it is certainly not less than 6 months or greater than 9 months. Perrotin confirms this slow rotation from observations of the markings on the disk made by him at Nice in 1890, and fixes it at from 195 to 225 days. In the same year Terby published a number of observations made by him in 1887–89 which appeared to him to still further confirm the slow duration of the rotation. But in 1891 appeared an important memoir by Niesten, giving the results of many observations made by himself and Stuyvaert at Brussels between 1881 and 1890. These observers, instead of supporting the slow rotation, strongly confirm the short rotation period of De Vico. They also found the markings so evident and apparently permanent that they were able to construct a map of them. This map, however, does not bear the slightest resemblance to that of Bianchini. More recently still, Trouvelot has discussed the subject, and decides that the rotation is performed in about 24 hours. . . . With results so contradictory, and obtained, too, by some of our very best observers, it is difficult to come to a satisfactory conclusion upon the subject. The balance of the evidence appears at present, however, to be in favor of a rotation in about 24 hours."

Since the above was written, Leo Brenner has entered the field on the short-period side. In 1895 he published several papers affirming strongly the rotation period of about 24 hours. Upon this Schiaparelli attacked the planet again, and from his observations of the practical motionlessness of four markings in July, 1895, concluded that the determination of the period of rotation which he had previously arrived at, one of 224.7 days, was now put entirely beyond reasonable doubt. Mascari in Sicily, notably upon Mount Ætna, and Cerulli in the north of Italy, made observations which led them to the same period; Mascari's having been made at intervals from 1892 to 1895.

But all of the markings observed partook of a certain indefiniteness of character, which weakened their testimony except to the observers themselves. To the keen insight of Schiaparelli they were sufficiently determinate to enable him to detect the rotation period, but they were not sufficiently so to carry conviction or proof of it to others.

Doubt of like character has enveloped the planet's physical condition. From the fact that they could make out next to nothing upon her surface observers have inferred the existence of dense clouds floating in her atmosphere, and obscuring to a greater or less degree any markings that might chance to lie underneath.

It has been supposed that the conditions prevailing on the planet were analogous to those of our own carboniferous period, when dense vapors overhung a vast tropically luxuriant vegetation. In consequence, the actual surface has been thought to be for the most part hidden during the greater portion of the time, and only occasionally revealed as through clouds and vapors, doubtfully and ill defined.

III.

Such was the state of our knowledge of our neighbor when, last August, occurred the observations I am about to describe. At the time they began the planet was just starting to be evening star. She was evening star, however, only in a technical sense; for so near was she yet to the sun that she was invisible to the naked eye unless it was carefully directed by calculation to her place in the sky. She had, in short, just passed what is known as superior conjunction, or that position, as viewed from the earth, in which she lies directly beyond the sun. She had passed it by only twelve degrees, or fifty minutes in time, at the date of the first observation. On account of this proximity to the sun it was necessary to observe her during the daytime, as she set too soon after him for even twilight observations to be possible. But even had it not been necessary to seek her by day, it would have been advisable to do so; for the atmospheric conditions near the horizon are never of the best, and if a heavenly body is to be seen well it must be observed when tolerably high above the horizon. Now, Venus, even at her farthest, departs so little from the sun that to see her well she must be sought before the sun has set.

Whether the day air would prove serviceable was the question. That the air was steady by night was no guarantee that it would be so by day; for not only is the atmosphere by day rarely so favorable to astronomical investigation as it is by night, but also the condition at the one period affords no criterion of the condition at the other. A place may be phenomenally good by night, and worthless by day. That the day air is worthless is the rule. Fortunately, Flagstaff proved the exception. The atmosphere by day there proved to be much better than I had anticipated. At times it was so excellent as to reveal the planet as if cut in steel against the sky.

The next open sesame was the use of low powers. This is a very important point in all planetary work, and one which is not generally appreciated. Misinformed by textbooks, most persons are under the erroneous impression that the higher the power used, the more will be seen; and the first question usually asked about a telescope is, How much will it magnify? There could hardly be a worse mistake. No planet will bear high magnification: partly from defects in the atmosphere, partly from optical effects of the interference of the light pencils refracted by the glasses. But true as this is of all the planets, it is especially the case with Venus, where the illumination is dazzling and the contrast of the details faint. Of the powers I tried, the best results came from one which magnified the planet's disk to about the size of the moon as seen with the naked eye. Any power which made her look more than four times as large as this was impracticable. And this not from lack of steadiness in the air, — for

I have seen her when, as I have said, her image approached the perfection of a steel engraving, — but from the faint contrast presented by different parts of her surface.

The planet entered the field of view looking much as the moon does when a day and a half from the full, only that the planet was much the more brilliant of the two; for in spite of the dazzle of the day its disk shone as the moon's does on a dark sky, while the latter, when seen by day after having been up all night, appears, as we all know, symptomatically pale.

The planet's disk was not equally bright throughout. It was brightest in the centre, and next brightest at the middle point of its full side, — what is technically called its limb. The side opposite this, known as the terminator, — because it is there that the light terminates, — looked shaded, in consequence of the fading away of the illumination; while the points where the limb and the terminator met, called the cusps, were brighter than the latter, but not so bright as the former. Now, the noting of these points may at first seem unimportant. We shall see later that it is far from that, and that from the concurrence of just such bits of evidence is conviction as to the planet's physical condition brought about. Our knowledge of our neighbor planets is, indeed, a bit of detective work. Simply to see is little or nothing without the brain behind to interpret the retinal images which are produced.

As for optical purposes all astronomical views are upside down, south upon the planet lay at the top of the disk, north at the bottom, west to the right, and east to the left. Such would be the orientation to one standing upon the planet in its northern hemisphere, in a position analogous to our own position upon the earth. The limb lying to the left hand marked, therefore, the east; the terminator on the right, the west.

So soon as the face of the planet came to be scanned, on the afternoon of August 24, it was evident that there were markings upon it. Especially was a certain spot apparent, situate in the lower left-hand portion of the disk. This spot was not only the first marking chronicled, but the first to be chronicled a second time, and thus admit of definite location. It was first seen just before three o'clock in the afternoon, and was drawn repeatedly till the close of observation, a little before six. Other markings, too, were drawn on the same day, but none of them with the certainty or precision due to the repetition observable in the spot.

The spot was considerably darker than the other markings, which was the cause of its repeated visibility. Being the first marking to be identified, it seemed fitting to call it Eros, a name it turned out to merit for another peculiarity, presently to be described.

The next marking to be identified was a long, curved band lying near the limb to the southeast of the spot, some six times as long as it was broad, and concave to the limb. This I called Psyche.

Almost contemporaneous with the unmistakable recognition of these markings was the detection of a projection near the upper end of the terminator; and a most salient one it was, — as large, to all appearance, as the irregularities upon the terminator of the moon, if not larger. A part of its height was doubtless due to irradiation, inasmuch as irradiation increases the apparent size of any bright object, but, as doubtlessly, a part of it was intrinsic, real. What it probably was we shall see a little later, when we come to consider it in the light of what was afterward observed. It was not the only prominence. Another, less high, showed near the northern cusp; while a less certain third could be made out about midway along the edge.

So much for what was visible from the start; interesting as all beginnings are interesting, but also because something was seen so soon. As time went on, however, study of the planet's surface became absorbing on its own account, for gradually more and more details became visible on the disk. Whether it were owing to increased faculty of perception born of constant attention, whether to increased size of image due to the planet's continual approach, or whether to possible improvement in the seeing that is in the state of the atmosphere, certain it is that as summer passed into autumn, features upon the face of the planet, at first will-o'-the-wispy and doubtful, grew unmistakably distinct. What had been fleeting and therefore questionable visions turned to indisputable facts. The markings which, to begin with, although patently there, had been undelineable because of the bo-peep-like character of their revelation, came to stand out with undeniable definiteness, absolutely differentiated each from its fellows. And a very curious and interesting map they combined to make.

It appeared that they were for the most part in the form of broad lines, lines of which the length was from five to ten times the breadth. Many of them were seemingly straight, and, roughly speaking, of the same width throughout. Others were curved and tapering. But what was the most surprising thing about them was the radiation of no less than eleven of them, and these among the most prominent, from a certain central point to the south and west of the centre of the illuminated disk. In spite, however, of their more or less regular form and singular association, they bore the look of being perfectly natural formations; that is, they had none of the appearance of artificiality, such as distinguishes the finer markings on Mars. They were much more like the markings on the moon, except that in form they bore the latter no resemblance, and were at the same time both more definite and less dark. In the best seeing, they were perfectly contoured; that is, their edges were sharp, causing the marking, notwithstanding the faintness, to stand out distinctly from the brighter surrounding portions of the disk.

This faintness was perhaps their next most striking trait, if the absence of conspicuousness may be considered a conspicuousness by the very fact of its absence. The markings on Venus are by far the least dark of all the planetary markings. It is for this cause that they have so long contrived to escape detection. Compared with the markings on Jupiter, Saturn, Mars, and Mercury, those on Venus are in tone delicate to a degree. Nor is this their only peculiarity on the score of faintness. It is not simply that the dark markings are less dark than one might expect, but also that the remaining bright portions are brighter. The disk looks as if over whatever markings or absences of them there might happen to be, underneath, a brilliant covering had been drawn, which made the dark ones seem less dark and the bright ones brighter than in reality they were. The reader may perhaps already surmise what this seeming covering was.

In addition to the long markings there were spots; some of them darker than the long markings, some not. Nor were all the long ones of equal tone, by any means, some being less faint than others. In places the spots lay on the long markings; in other places, off them.

Another very striking and very interesting feature about the planet was the complete absence of colors. The disk was one universal straw color throughout, a chiaroscuro in pale yellow. It was as if the markings made a background of black and white, over which lay drawn a straw-colored veil. None of the diversified tints of Jupiter and Saturn, none of the beautiful hues of Mars, were visible there. Compared with the other members of the solar family, Venus appeared a very drablike thing.

Such, with minor changes, was the general appearance of the planet during the period of observation, from August 24 to November 9. During this time a great number of drawings were made of her; and for the last six weeks of it so very distinct were the markings that they could be seen almost without exception, wherever she was looked at.

IV.

Having thus seen what the telescope revealed of the markings on the planet, we will now proceed to see what these markings tell us of the physical characteristics of the planet, and as a first stepping-stone to such knowledge what they have to say about the planet's day.

If it be possible to detect markings upon a planet's disk which are permanent and permanently visible, it is at once possible to determine the planet's rotation period. For if we make drawings or measurements of the positions of the markings at different times, and then compare the several drawings or deduced positions with one another, we shall be able, by the shift of the markings thus disclosed, to tell how they have moved in the interval; and since they are all upon one and the same globe, by the principles of spherical trigonometry we can deduce the position of the axis round which they turn and the rate at which they are turning. Not only can we do this with accuracy, if we take our intervals sufficiently far apart, but it will probably surprise most readers to learn in how short an interval it is possible to detect in this manner, in one of our neighbor planets, a rotation like that of our own earth. If an observer armed with one of our modern large telescopes were placed at a distance of forty millions of miles from the earth, the distance that Mars was from us at the last opposition, two minutes would suffice to show him that the earth was rotating under his gaze. In two minutes, supposing our seas and continents to be free from cloud and not too much obscured by atmosphere, it would be apparent to him that these seas and lands had shifted in position with regard to the centre of the visible disk. We know this because this is precisely what happens in the case of Mars. Roughly speaking, Mars rotates in the same time as the earth, — taking, instead of about twenty-four hours, about twenty-four hours and forty minutes in the process; that is, about a thirty-sixth part longer than the earth does. But Mars being much smaller than the earth, only about one half as big, his surface is carried round more slowly, in just the same proportion; that is, about one half as swiftly. Now, to one watching the planet in good air, four minutes suffice to show that the markings have moved. So accurately, indeed, may one detect such change of position in the surface of the planet, that if our own air be steady it is possible to time the passage of a marking across the planet's central meridian to within a minute, one way or the other; and this, be it remembered, at a distance of forty millions of miles away.

In fact, in the case of Mars, it is scarcely possible to make consecutive drawings of his disk without having them show the effect of the rotation unmistakably, inasmuch as some time is necessary to make each drawing. To one who looks at the drawings of Venus made at Flagstaff, the very first glance will be enough to disclose a totally different state of things. Instead of showing an unmistakable shift in the markings, consecutive drawings display the same marking in the same place. Not only is no variation perceptible from minute to minute, but none is discernible from hour to hour, nor from day to day. As the most instantly convincing instance of this immovability we may take the portraits of the planet made on the afternoon of October 15. On that day I made a series of drawings covering a period of five hours, — the first at noon, and the others at from one to two hours' interval afterward, until just before five o'clock. The air was good throughout, and the markings came out distinctly in all. On comparing these drawings, the identity of the several markings presented by them is evident at a glance, and in all of them the markings appear depicted in the same places.

But during these five hours the planet, on the supposition of a twenty-four-hour period, like that of Mars or our own earth, would have rotated through 75°. Such a change of angle would have caused the markings near the centre of the disk to travel five eighths of their apparent course across it. They had not shifted at all. Consequently, not only was a twenty-four-hour period for Venus's day out of the question, but any period at all approaching it was clearly impossible. It was evident that in the case of Venus the rotation period was to be reckoned, not in hours, but in days. It being thus demonstrated what it was not, it remains now to determine what it was.

In regard to this a certain feature in the presentation of the markings served to make the positive determination as unmistakable as the negative one had been. This feature was the following one: —

If the rotation of a planet be performed in any less time than the planet takes to complete its circuit of the sun, the markings will appear to cross the disk, irrespective of how much or how little of that disk be illuminated. They will first become visible upon the boundary of the light and shade, and will then proceed to advance across the face of the planet, if the boundary of the light and shade be the sunrise one, and the rotation be from west to east as with the earth, until they sink out of sight beyond the visible edge upon the other side. They will travel more and more slowly in proportion as the rotation is less swift. But they will always gain upon the phase, and travel faster than the illumination or the lack of it over the face of the planet, so long as the period of their rotation is less than that of the planet's revolution in its orbit.

If, now, we suppose the rotation to be performed in a longer and a longer period, there will come a time when this will cease to be the case, and the markings will no longer gain upon the advancing phase. This seeming halt will occur when the angular rapidity of the rotation and the angular rapidity of the revolution become the same.

If a planet move in a circular orbit about the sun, and rotate on an axis perpendicular to its orbital plane once during the time it takes to perform its circuit, a curious result will follow in the appearance the planet will present to an observer watching it from without: the markings upon it will always hold the same position with regard to the terminator. They will seem to cling to it as origin, no matter how much or how little of the illuminated disk be presented to view. The same feature will be visible on the terminator when the disk is nearly full, and still be upon the terminator when that disk has diminished to a slender crescent. All the markings will disappear over the limb in due course, those farthest from the terminator going first, the others in their order, but each will preserve throughout its own distance from the boundary of light and shade. The terminator, in short, will be a sort of natural origin of longitudes. Reckoned from it, the position of the markings will never change.

That such a curious case of immovable movability must result in the aspect of the markings from the given relation of the rotation to the revolution will appear when we consider that if the rotation and the revolution be performed in the same time, the planet must continuously present the same face to the sun; and since the sun is not only the attracting but the illuminating body, this means that the illuminated hemisphere of the planet must forever be the same. However, therefore, an observer be situated with regard to the planet in question, the position of the markings on the illuminated hemisphere, being continually the same, must maintain the same relative distance from its boundaries. Curious as this result is, we shall see farther on that it is yet more curious in the results it brings about.

If we compare this case of coincident rotation and revolution with another with which we are more familiar, namely, that of the moon in her monthly journey about the earth, we shall be struck by an interesting difference. The moon always keeps the same face toward her primary. But in the case of the moon the markings seem fixed, while the illumination seems movable, and consequently the light and darkness appear to sweep slowly over them, making a complete circuit in the course of a lunation. Now, this difference of aspect in the two cases comes from the fact that with the moon the attracting and illuminating bodies are not the same. Her primary is not also, as with Venus, the cause of her illumination. The moon, indeed, turns always the same face to the earth, but that face is not necessarily her illuminated one, because her illuminated one is always directed to the sun, and sun and earth are not always in the same direction as seen from the moon. The moon, in fact, instances the second out of three possible phenomena due to coincident rotation and revolution, — the three differing from one another solely in consequence of the point of view. The three cases are these: the observer may be situated at the centre of both the attraction and the illumination, or at the centre of attraction alone, or at neither. In the first case, neither the illumination nor the position of the markings will ever change; in the second, the position of the markings will not change, but the position of the illumination will; in the third and last, the position of the markings and that of the illumination will change together. The first of these standpoints is for us impracticable, constituted as we are, inasmuch as we cannot put ourselves upon the surface of the sun, and should doubtless object to making the experiment, even if we could; the second of them is the one we hold with regard to the moon; while the third and last is the one we are placed in with regard to the planet Venus.

That this last is the fact the drawings disclosed unmistakably. Drawing after drawing, and day after day, showed the same features at the same relative distance from the boundary of the light and the darkness. Although with time the boundary itself shifted slowly across the face of the disk, the markings still kept their relative distances from it unchanged. With its shift they shifted too, and so closely did the two keep pace that not only could the eye detect no disagreement, but none was shown by careful measurements, afterward, of what the eye had seen. For on examining critically the markings in the several drawings it appears that the one point about all of them which is invariable is their relation to the terminator.

As the planet came out of the neighborhood of the sun, getting daily farther and farther off from him, the phase increased; that is, the line of demarkation between the illuminated and unilluminated portions of the disk shifted slowly across it to the left. As it did so, the markings, as I have said, shifted with it, *pari passu.* Those that had at first appeared upon its edge remained upon its edge, and those that were originally at a distance from it kept that distance, except for the effect of perspective, unchanged. This is conclusively shown by the drawings. But it is even more conclusively shown by them than it seems to be. The drawings are even more telltale than they look. And for the following reason: during the period of time in which the drawings were made, our earth was not stationary, but in the act of running away, as it were, from Venus, which was following at a yet more rapid rate, and in consequence gradually catching up with us. Had we been stationary, the increase of phase in Venus would have exactly marked the amount of her change of place in her orbit, the angle through which she had revolved about the sun in the course of the interval. As we were not stationary, her increase of phase marked only the amount she had gained upon us during that time, which of course was something far less than the distance she had actually traversed. It was what she had traversed less what the earth had traveled in the mean time. But as the earth's angular movement around the sun is about two thirds that of Venus, the difference between the two was only about one third of the actual revolution of Venus herself. In other words, three times the changes recorded by the drawings really took place in the angle of revolution. But as no such factor affected the perception of her rotatory motion, the latter had a chance to show its full effect except as the angle between the two planets altered it, and this angle bore a smaller and smaller proportion to the other, the increase of phase, as the period of the supposed rotation differed from the period of revolution. Only in the event of synchronism between the two could it attain the same value as in the case of the phase. Consequently, in the event of disagreement the markings would have shown a divergence greater than the drawings would seem at first to be able to indicate.

Although the drawings thus testified conclusively to the synchronism of the two motions, I was minded to ascertain just how great the accuracy of their testimony might be. For this purpose I took the drawings from October 1 to November 9 and measured upon all of them the consecutive positions of a certain spot. The spot I chose was the one from which the eleven lines previously described radiate, a spot which I have called Bilit. In order to insure as great accuracy as possible, I did not trust to the eye for the amount of the phase; for to tell at a glance just how much a gibbous disk lacks of being full is not an easy matter. Instead, I calculated the theoretical amount of the phase for each day, and then made upon it the following necessary practical correction.

As the light fades away gradually at the boundary of light and shade, it is not possible, in the case of a bare globe, for the eye to see quite out to the limit of illumination, as we perceive in the case of the moon. On the other hand, if a globe be encompassed by an atmosphere, that atmosphere, by producing the phenomenon of twilight, will sensibly increase the apparent limit of the light. This we have evidence of in the case of Mars. To tell, therefore, what in any special case that limit may be, it is necessary to make measures of it for the particular planet at the particular time. This is done by measuring the phase diameters, — that is, the diameters perpendicular and parallel to the loss of light, — and comparing the consequent result with the calculated value. This I did. The result, combined with the measure of the position of the particular marking on the visible part of the disk, gave me its true observed position.

Now, the positions so deduced agreed surprisingly with one another. They came out so closely the same with regard to the terminator as to show that as concerned that terminator the markings had evidently not moved in the mean time; for it appeared that the difference in longitude of the first and last values agreed within half a degree with the difference in longitude of the terminator during the same period. At the same time, the average error of the drawings for any one day proved to be about a degree. In other words, the agreement of the markings with the terminator at the beginning and at the end of the interval turned out to be about half of the probable error of any one determination of the position of the markings. Such a remarkable coincidence was of course fortuitous, since it was actually closer than the degree of possible accuracy in the observations, but it showed that the agreement exceeded the possibility of detecting its error.

The advantage of selecting Bilit for measurement lay in the fact that during the interval taken it passed the central meridian of the disk. Therefore, from being viewed less obliquely, its apparent shift was the greatest possible, and was also the least exposed to faulty eye estimates.

V.

The fact that the planet of love turns always the same face to her lord, the sun, has very far-reaching consequences. As a preliminary to a consideration of them we may note one result of the fact which, although possessing no cosmic importance, has a very direct interest from a terrestrial point of view. That Venus shows always the same face to the sun means that we shall never see more than one half of her; for although she turn toward us all parts of her surface in the course of her circuit of the sun, her illuminated half, which is the only part of her that we can see, remains forever the same. Thus one hemisphere of hers alone shall we ever be able to scan; of the condition of the other we shall only be able to make inference. With increasing appliances for gathering knowledge, we may come to prediction of what it would look like could we look upon it, but see it with our bodily eyes we never shall. The night side of the planet of love must remain something of a mystery forever.

What is true for us in this case is true for every other outsider in space. It would not help us to travel to Mercury or Mars or Jupiter for increase of vision in the matter. What is true for one outsider is true for all. The side the sun does not light up must remain hid in perpetuity from observers everywhere.

Such, however, is but a third-person detail. The isochronism of rotation and revolution has very much more important because very vital consequences for the planet herself. As the planet possesses an atmosphere, some of the most weighty of these consequences would come from the meteorologic conditions which must result upon her.

What these are it is well-nigh startling to consider. The same hemisphere being continuously illuminated, the same parts of that hemisphere would be exposed to the sun to the same extent in perpetuity. To begin with, then, whatever the effect at any point of the surface, that effect must be a constant one at that point, since like conditions prevailing perpetually must in the course of ages, if not before, result in bringing about a state of stable motion.

The part of the surface to receive the greatest amount of heat — insolation, as it is technically called — must be that directly under the sun, which would be the centre of the illuminated hemisphere. This, therefore, would be the most heated. In consequence, the air above it would be the most expanded and would rise most rapidly, while the air from the regions round about would rush in to fill its place. The spots they left would in turn be filled from regions more remote, and this state of replacement would continue till the night side was reached.

There would thus be set going a funnel-like indraught of air from the centre of the dark side to the centre of the bright one. The surface air would flow from the one to the other. Meanwhile, a counter umbrella-like current would set overhead in the opposite direction, to restore the equilibrium to the other hemisphere.

If there were water present on the planet, and, we will suppose, originally on both sides alike, it seems probable that its career would be as follows: As the heated air ascended from the centre of the illuminated side, it would become chilled as it expanded, and, being unable to hold its moisture, would proceed to deposit it in the form of showers. Most of the moisture it held would thus at once be parted with, but not all. A little would be carried round by the air to the dark side, where, experiencing a yet greater degree of cold, it would be left as ice, and as ice there it would remain; for the amount of moisture which the exceedingly cold air, on its return journey, could support would be a minute quantity; so that although the ice would tend slowly to evaporate, very little of the water vapor would find its way back to the bright side.

There would thus be a constant drain of water from the bright side to the dark; for however little might go over at a time, practically none would ever come back. Eventually, therefore, under this continued state of things, all the water would be withdrawn from the illuminated side, and piled up on the dark one in the form of glacier ice.

On the bright side of the planet there would thus be no oceans or seas or rivers or ponds, not even water vapor in the air, while glaciation would more or less completely cover the other. The side we see would be one vast desert; the side we do not, fields of perpetual ice.

Some corollaries from this are interesting. One of these is that there should be no visible polar caps, since there would be, not polar caps, but a polar hemisphere. And this would be forever hid from us, for nothing but orbital or axial libration — that is, a swing of the portion of the disk under illumination — could bring it into view; and in the case of Venus the orbital libration is insensible, and the axial one apparently so.

Another ingenious corollary has been suggested by my friend Mr. Godfrey Sykes. It is that the phosphorescence, as it is called, of the dark side, a faint light upon it which has hitherto evaded explanation, may be caused by the reflection from the ice-fields there of the light received from the earth, the other planets, and the stars.

VI.

From the determination of the planet's day, and the deductions from its duration as to the physical conditions of the planet's surface, we may now turn to what the aspect of the planet's disk in general and of the markings upon it in particular has to say about these same physical characteristics.

The initial noteworthy point about the markings was their faintness, and, furthermore, the fact that this faintness was general. It was not confined to any special markings or set of markings, but was common to all. Next, it was not even confined to the markings themselves, but was shared by the bright portions of the disk as well. It was, in fact, as we have seen, as if some bright covering had been drawn over the whole disk. Now, from what we know in other ways about the planet, it is pretty evident what this bright veil was; namely, nothing more nor less than atmosphere. That Venus has an atmosphere we know from the bright aureole seen about her in transit, and from the extension of her horns beyond their due limits when she is a crescent. In the case of a planet with an atmosphere, that atmosphere, to an observer looking plumb down upon the disk, would make itself apparent in precisely such a brightening of the whole disk as we here observe. Atmosphere enveloping the planet would produce just such an effect, and nothing else that we can think of would. This, taken in connection with the aureole and the extended horns, is about as conclusive evidence as we could have that what brightens her disk and gives to Venus her surpassing lustre to the naked eye is an atmosphere about her.

As the atmosphere of Venus has generally been thought to be dense, and as there is as yet no reason to suppose that it is not, in density at least, much like our own, the visibility of the markings through it leads us to infer that perhaps our own, on a clear day, are not so hidden as some recent investigations with regard to the concealing capacity of our air have given us reason to think.

The next suggestive fact in connection with the markings is their permanent visibility. The markings were never invisible save when our air was too bad to show them. Such perpetual appearance proves that there is nothing between us and them to shut them off from view at any time. Therefore there are no clouds in the planet's air, over any part of the planet's surface, at any time. It is not wholly ill fitting that Venus should thus be ever fair.

At this point we may take up the consideration of what the prominences may have been, notably the striking one a little to the west of the southern cusp, seen not only at the start, but on to the close of observations, months afterward. *A priori,* two suppositions are open to us in explanation of it: one that it was cloud, the other that it was mountains. But from the two facts, first that there are no clouds otherwise visible upon the planet's surface, and second that the prominence remained always visible in the same place for months, the supposition that it was cloud becomes inadmissible, and we are left with the sole alternative that it was mountains.

So much for air. As for water, there is, to begin with, no sign of any polar caps. What has hitherto been taken for such caps is, I think, the effect of the two projections: one near the southern, the other at the northern cusp. I infer this from the Flagstaff observations. Although I have thought I saw bright regions at the cusps, I have much more frequently noticed none; and what is yet more to the point, even those semblances markedly lacked the certainty and brilliancy of the caps of Mars. Furthermore, they were seen early in the observations of Venus, before I had got accustomed to her. On the other hand, as recorded above, I have noted the centre of the disk to be the brightest part, and the centre of the limb to be more brilliant than the cusps. The outcome of my observations is that Venus has no polar caps.

Not only is there no evidence of polar caps; there is no evidence, either direct or indirect, of water in any form on the illuminated part of the planet. This inference is, rather interestingly, I think, a question of color; for color as well as form may prove a telltale thing. Now, the surface of Venus, as we saw a little way back, is practically colorless. The beautiful hues which make of Mars an opal, a fire-opal, are wanting on her. There is neither red, nor blue, nor green; only a universal palish yellow, diversified in form, but the same in tint. And even the pale yellow is but her atmosphere, through which we look, since it colors all alike.

Such lack of color means much more than mere absence of personal beauty as a planet. It shows, indeed, to begin with, that the surface has no very distinctive color anywhere. But it connotes a deal more; for it betokens, first the absence of water, and secondly the lack of vegetation there. This means the absence of life, for it means the presence of conditions under which all life that we wot of must be impossible.

How strikingly destitute of local color Venus is becomes particularly patent on comparison with Mars. We might suppose, a priori, that atmosphere itself might be responsible for the resulting sameness of tint. But Mars shows it to be otherwise; for though Mars possesses an atmosphere, this atmosphere proves no bar to the recognition of his surface tints. In good air the colors on Mars are most marked. Daylight intensifies them. So that the fact that Venus has presumably more air is to a certain extent offset by the fact that she was observed by day. If there were upon her surface any decided tints, they should, it would seem, come out under these conditions. Yet they are conspicuous only by their absence. All of the observers at Flagstaff have noted the planet's lack of color, the singular lack of color on her disk. She is as colorless as the moon to the naked eye. Any color she may possess is not more than would be given by the hue of different rocks or soils, and not very variegated ones at that. The look of the whole of her illuminated half is that of one vast desert. This perfectly agrees, it will be remembered, with what we deduced as the result of the duration of her day.

VII.

After having thus seen the effect of isochronous rotation and revolution upon the physical condition of a planet, it becomes interesting to inquire into its cause.

What does such a turning always of the same face to the sun mean? We have seen what it probably has produced, — for the planet a living death; now arises the question whether this death be of the nature of a cosmic accident, or whether it be a death due to natural causes, the inevitable ending of the planet's term of life. The answer to the question leads us to the latest advance in our knowledge of cosmic evolution.

When La Place wrote his masterly paper on the tides, which he himself accounted the greatest part of his analysis of the mechanism of the heavenly bodies, he little thought that the tides he was considering, those raised by the moon in the ocean, were a comparatively insignificant manifestation of a fundamental force. He little dreamed that the researches of his successors would prove tidal action to have been the most important factor in the fashioning of the universe. Yet so it has been. The recognition of tidal action has worked the greatest advance that has been made in celestial mechanics since La Place's time, and it is to the younger Darwin, in our own day, that the world is indebted for it.

The general principles of the matter may be understood without any call upon mathematics, such as their pursuance into proof and detail demands. To begin with, it must not be supposed that the subject is limited to our everyday tides, or even chiefly concerned with them. It should be said at the outset that the tidal action under consideration is something far more important, because far more effective and far more comprehensive, than what we are commonly accustomed to consider as typical tidal action, the tides raised in our seas and oceans by the sun and moon. Superficial tides such as these upon a planet, although they seem to be of some magnitude to dwellers upon that planet, are of much less account, relatively speaking, than are another class of tides, — those, namely, which affect the bodies as a whole; substantial tides, as they may be called. The forces brought into action in the two cases are indeed the same, and their effects differ only in amount and in detail. At present, upon the earth, we have evidence only of the superficial kind, but beyond a doubt there was a time in her history when such was not the case, a time when she was swayed by bodily tides; and these same bodily tides have left their imprint upon the whole earth-moon system. More than this, they have made it what it is.

Suppose two rotating masses of fluid matter, — those which were to form the earth and moon, for instance, — the one revolving about the other and in close proximity to it. Each would set up tides in the other; because each, by attracting the parts of the other unequally, would disturb their uniform rotation. This is worth stating correctly, inasmuch as in textbooks on astronomy it is almost universally stated wrong. Even in the very best of them the reader is given to believe that the effect of the unequal attraction to which the body is subjected would be the production of bulges upon it in a line joining the centres of the two bodies, which bulges would then be caused by friction to lie a little ahead of that line. This, however, is quite erroneous; it is an explanation of the tides that will in no sense hold water. Bulges would be caused, indeed, but they would not lie in a line joining the centres of the two bodies, but nearly at right angles to such a line; and friction, instead of causing them to lie a little ahead of where they otherwise would lie, would cause them to lie somewhat farther back. That position being, however, some ninety degrees ahead of the line joining the centres of the bodies, the result would be that the protuberances would still lie ahead of the line. The double error of the textbooks explains in part its non-detection. As the tide-protuberances would lie somewhat in advance of the line joining the centres of mass of the two bodies, each would tend to pull the other ahead of where it otherwise would be, thus directly increasing its orbital speed, and so indirectly the size of its orbit. In other words, the tides would tend to separate the bodies farther and farther, until their action ceased.

Such, then, was the genesis of the earth-moon system.

Now, Dr. See has shown that this has undoubtedly been the mode of genesis of the double-star systems as well. In La Place's time it was not supposed that a nebula could break up ordinarily into two masses of anything like equal size, but since then Poincaré and Darwin have proved that it is possible, and the further researches of See have shown that it actually has happened in the case of the binary stars. So potent a factor, then, is tidal action in the beginnings of solar system evolution.

In a different way tidal action must be an equally potent factor in bringing the careers of the two bodies to a close. Just as tidal action makes of one body two, so does it tend eventually to make both, physically speaking, dead; for the same force which causes them to grow farther and farther apart causes, reversely, each to turn more and more completely the same face to the other. Just as the action of the tides accelerates the one in its orbit, so does it retard the other in its rotation; for it is evident that as the main part of the body turns while the bulge is held relatively stationary, friction will cause a slowing up of the speed with which the main part turns. It is furthermore evident that this brake upon the body's rotation will continue to act so long as the body turns at a rate faster than the bulge itself does. But the bulge turns only as fast as the second body moves in its orbit, the bulge pointing constantly a trifle ahead of the place that body occupies. Consequently, the rotation of the one body will steadily be made slower and slower, until in course of time it is brought down to the same angular speed as that of the other body in its orbit. When the body has once attained this rate of rotation it will continue to keep it, inasmuch as then there will be no force acting to change it further.

This effect will be visible first in the smaller body, owing to its less moment of rotation. This is precisely what we observe in the case of the earth-moon system. The isochronism of rotation and revolution has already taken place in the case of the moon, and is in process of taking place in the case of the earth. For Darwin calculates that originally they may both have rotated, at the moment of separation, in about two hours and forty-one minutes; while now the moon has been slowed down from this to twenty-eight and a half days, and the earth only to twenty-four hours. It is possible, indeed, that so potent was the earth that the moon may never have been allowed to rotate faster than she revolved. So that the moon may have been, so to speak, born dead.

It was the earth-moon system that suggested to Darwin's mind to investigate the cause; and that resulted in the detection of tidal action as a cosmic constructive force. No other instance, however, was then known or even suspected, except in the case of Iapetus, the eighth satellite of Saturn, which was conjectured, from the variability in its light, to turn always the same face to its primary. The fact, therefore, that Venus and Mercury — for as we shall see in another paper the same is true of him — turn out always to face their primary, the sun, is of great theoretical interest, for it is the first certain specimen of tidal friction, other than the moon, presented to us, and is of proportionate moment toward proving the universality of the law.

That Venus and Mercury should be the first planets to show this ultimate sign of decrepitude is what was to have been expected, if such sign were to be shown at all. This is so for the following reasons: The tide-raising force exerted by the sun is not the same for the several planets. It diminishes very rapidly with the distance from him; more rapidly, indeed, than the force of gravity itself. For it is a differential effect of gravity, since it depends upon the difference of the sun's attraction upon different parts of the planet. In consequence of this it varies, not as the inverse square of the distance, but as the inverse cube of it.

Even this does not measure the full proportionate effect of the tidal force in slowing up the spin of the several planets. For the couple produced by the two bulges is itself proportionate to the inverse third power of the planet's distance from the sun. So that the effective tidal action varies inversely as the sixth power of that distance. We see, therefore, how very rapidly it diminishes as we leave the vicinity of the sun. For Mercury it is between two and three hundred times, and for Venus about seven times, as great as it is for the earth; while for the earth, again, it is much greater than it is for Mars, and very much greater than for any of the planets outside of him.

We can understand, therefore, how it came about, in the case of Venus, that the axial machinery ran down so soon. We can see why long ago it went more and more slowly, until, her axial and her orbital motion coinciding, she was left motionless, changeless, dead.

In Venus, then, we gaze upon a world which as a world has run its course. Beautiful as she appears to us, as she glows and sparkles on the twilight sky, it is distance alone that gives her her seeming loveliness and endows her with eternal youth. In truth she is far otherwise. All the comeliness she may have had in the morning of her prime, when the solar system itself was young, has gone from her never to return. As the Japanese prettily put it of a woman, the cherry blossom has passed into the leaf. For she is no longer young; she is old, wrinkled, dead. Or shall we not better say she sleeps, though it be with the sleep from which there is no awakening? For it is fitting that she should still seem so fair to us, when she glows athwart the gloaming in the slowly fading sky, — fitting that the planet of love should seem lovely to the end.

Percival Lowell.