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Their Nature, Possibilities and Habitability in the Light of the Latest Discoveries

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OTHER WORLDS

BY GARRETT P. SERVISS.

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popular interest in the wonders of the starry heavens has been stimulated by surprising discoveries and imaginary discoveries, as well as by a marked tendency of writers of fiction to include other worlds and their possible inhabitants within the field of romance.

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CHART OF MARS. After Schiaparelli.

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Other Worlds

Their Nature, Possibilities and Habitability in the light of the latest discoveries.

By GARRETT P. SERVISS

Author of

“Astronomy with an Opera-glass” and “Pleasures of the Telescope”

With Charts and Illustrations

“Shall we measure the councils of heaven by the narrow impotence of human faculties, or conceive that silence and solitude reign throughout the mighty empire of nature?”

—DR. THOMAS CHALMERS.

New York
D. APPLETON AND COMPANY
1901

TO
The Memory
OF
WILLIAM JAY YOUMANS.

PREFACE

The point of view of this book is human interest in the other worlds around us. It presents the latest discoveries among the planets of the solar system, and shows their bearing upon the question of life in those planets. It points out the resemblances and the differences between the earth and the other worlds that share with it in the light of the sun. It shows what we should see and experience if we could visit those worlds.

While basing itself upon facts, it does not exclude the discussion of interesting probabilities and theories that have commanded wide popular attention. It points out, for instance, what is to be thought of the idea of interplanetary communication. It indicates what must be the outlook of the possible inhabitants of some of the other planets toward the earth. As far as may be, it traces the origin and development of the other worlds of our system, and presents a graphic picture of their present condition as individuals, and of their wonderful contrasts as members of a common family.

In short, the aim of the author has been to show how wide, and how rich, is the field of interest opened to the human mind by man's discoveries concerning worlds, which, though inaccessible to him in a physical sense, offer intellectual conquests of the noblest description.

And, finally, in order to assist those who may wish to recognize for themselves these other worlds in the sky, this book presents a special series of charts to illustrate a method of finding the planets which requires no observatory and no instruments, and only such knowledge of the starry heavens as anybody can easily acquire.

G.P.S.

BOROUGH OF BROOKLYN, NEW YORK CITY,
September, 1901.

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CHAPTER I

INTRODUCTORY

Other worlds and their inhabitants are remarkably popular subjects of speculation at the present time. Every day we hear people asking one another if it is true that we shall soon be able to communicate with some of the far-off globes, such as Mars, that circle in company with our earth about the sun. One of the masters of practical electrical science in our time has suggested that the principle of wireless telegraphy may be extended to the transmission of messages across space from planet to planet. The existence of intelligent inhabitants in some of the other planets has become, with many, a matter of conviction, and for everybody it presents a question of fascinating interest, which has deeply stirred the popular imagination.

The importance of this subject as an intellectual phenomenon of the opening century is clearly indicated by the extent to which it has entered into recent literature. Poets feel its inspiration, and novelists and romancers freely select other planets as the scenes of their stories. One tells us of a visit paid by men to the moon, and of the wonderful things seen, and adventures had, there. Lucian, it is true, did the same thing eighteen hundred years ago, but he had not the aid of hints from modern science to guide his speculations and lend verisimilitude to his narrative.

Another startles us from our sense of planetary security with a realistic account of the invasion of the earth by the terrible sons of warlike Mars, seeking to extend their empire by the conquest of foreign globes.

Sometimes it is a trip from world to world, a kind of celestial pleasure yachting, with depictions of creatures more wonderful than—

> “The anthropophagi and men whose heads
> Do grow beneath their shoulders”—

that is presented to our imagination; and sometimes we are informed of the visions beheld by the temporarily disembodied spirits of trance mediums, or other modern thaumaturgists, flitting about among the planets.

Then, to vary the theme, we find charming inhabitants of other worlds represented as coming down to the earth and sojourning for a time on our dull planet, to the delight of susceptible successors of father Adam, who become, henceforth, ready to follow their captivating visitors to the ends of the universe.

In short, writers of fiction have already established interplanetary communication to their entire satisfaction, thus vastly and indefinitely enlarging the bounds of romance, and making us so familiar with the peculiarities of our remarkable brothers and sisters of Mars, Venus, and the moon, that we can not help feeling, notwithstanding the many divergences in the descriptions, that we should certainly recognize them on sight wherever we might meet them.

But the subject is by no means abandoned to the tellers of tales and the dreamers of dreams. Men of science, also, eagerly enter into the discussion of the possibilities of other worlds, and become warm over it.

Around Mars, in particular, a lively war of opinions rages. Not all astronomers have joined in the dispute—some have not imagination enough, and some are waiting for more light before choosing sides—but those who have entered the arena are divided between two opposed camps. One side holds that Mars is not only a world capable of having inhabitants, but that it actually has them, and that they have given visual proof of their existence and their intelligence through the changes they have produced upon its surface. The other side maintains that Mars is neither inhabited nor habitable, and that what are taken for vast public works and engineering marvels wrought by its industrious inhabitants, are nothing but illusions of the telescope, or delusions of the observer's mind. Both adduce numerous observations, telescopic and spectroscopic, and many arguments, scientific and theoretic, to support their respective contentions, but neither side has yet been able to convince or silence the other, although both have made themselves and their views intensely interesting to the world at large, which would very much like to know what the truth really is.

And not only Mars, but Venus—the beauteous twin sister of the earth, who, when she glows in the evening sky, makes everybody a lover of the stars—and even Mercury, the Moor among the planets, wearing "the shadowed livery of the burnished sun," to whom he is "a neighbor and near bred," and Jupiter, Saturn, and the moon itself—all these have their advocates, who refuse to believe that they are lifeless globes, mere reflectors of useless sunshine.

The case of the moon is, in this respect, especially interesting, on account of the change that has occurred in the opinions held concerning its physical condition. For a very long time our satellite was confidently, and almost universally, regarded as an airless, waterless, lifeless desert, a completely "dead world," a bare, desiccated skull of rock, circling about the living earth.

But within a few years there has been a reaction from this extreme view of the lifelessness of the moon. Observers tell us of clouds suddenly appearing and then melting to invisibility over volcanic craters; of evidences of an atmosphere, rare as compared with ours, yet manifest in its effects; of variations of color witnessed in certain places as the sunlight drifts over them at changing angles of incidence; of what seem to be immense fields of vegetation covering level ground, and of appearances indicating the existence of clouds of ice crystals and deposits of snow among the mountainous lunar landscapes. Thus, in a manner, the moon is rehabilitated, and we are invited to regard its silvery beams not as the reflections of the surface of a desert, but as sent back to our eyes from the face of a world that yet has some slight remnants of life to brighten it.

The suggestion that there is an atmosphere lying close upon the shell of the lunar globe, filling the deep cavities that pit its face and penetrating to an unknown depth in its interior, recalls a speculation of the ingenious and entertaining Fontenelle, in the seventeenth century—recently revived and enlarged upon by the author of one of our modern romances of adventure in the moon—to the effect that the lunar inhabitants dwell beneath the surface of their globe instead of on the top of it.

Now, because of this widespread and continually increasing interest in the subject of other worlds, and on account of the many curious revelations that we owe to modern telescopes and other improved means of investigation, it is certainly to be desired that the most important and interesting discoveries that have lately been made concerning the various globes which together with the earth constitute the sun's family, should be assembled in a convenient and popular form—and that is the object of this book. Fact is admittedly often stranger and more wonderful than fiction, and there are no facts that appeal more powerfully to the imagination than do those of astronomy. Technical books on astronomy usually either ignore the subject of the habitability of the planets, or dismiss it with scarcely any recognition of the overpowering human interest that it possesses. Hence, a book written specially from the point of view of that subject would appear calculated to meet a popular want; and this the more, because, since Mr. Proctor wrote his Other Worlds than Ours and M. Flammarion his Pluralité des Mondes Habités, many most important and significant discoveries have been made that, in several notable instances, have completely altered the aspect in which the planets present themselves for our judgment as to their conditions of habitability.

No doubt the natural tendency of the mind is to regard all the planets as habitable worlds, for there seems to be deeply implanted in human nature a consciousness of the universality of life, giving rise to a conviction that one world, even in the material sense, is not enough for it, but that every planet must belong to its kingdom. We are apt to say to ourselves: "The earth is one of a number of planets, all similarly circumstanced; the earth is inhabited, why should not the others also be inhabited?"

What has been learned of the unity in chemical constitution and mechanical operation prevailing throughout the solar system, together with the continually accumulating evidence of the common origin of its various members, and the identity of the evolutionary processes that have brought them into being, all tends to strengthen the *a priori* hypothesis that life is a phenomenon general to the entire system, and only absent where its essential and fundamental conditions, for special and local, and perhaps temporary, reasons, do not exist.

If we look for life in the sun, for instance, while accepting the prevalent conception of the sun as a center of intense thermal action, we must abandon all our ideas of the physical organization of life formed upon what we know of it from experimental evidence. We can not imagine any form of life that has ever been presented to our senses as existing in the sun.

But this is not generally true of the planets. Life, in our sense of it, is a planetary, not a solar, phenomenon, and while we may find reasons for believing that on some of the planets the conditions are such that creatures organized like ourselves could not survive, yet we can not positively say that every form of living organism must necessarily be excluded from a world whose environment would be unsuited for us and our contemporaries in terrestrial life.

Although our sole knowledge of animated nature is confined to what we learn by experience on the earth, yet it is a most entertaining, and by no means unedifying, occupation, to seek to apply to the exceedingly diversified conditions prevailing in the other planets, as astronomical observations reveal them to us, the principles, types, and limitations that govern the living creatures of our world, and to judge, as best we can, how far those types and limits may be modified or extended so that those other planets may reasonably be included among the probable abodes of life.

In order to form such judgments each planet must be examined by itself, but first it is desirable to glance at the planetary system as a whole. To do this we may throw off, in imagination, the dominance of the sun, and suppose ourselves to be in the midst of open space, far removed both from the sun and the other stars. In this situation it is only by chance, or through foreknowledge, that we can distinguish our sun at all, for it is lost among the stars; and when we discover it we find that it is only one of the smaller and less conspicuous members of the sparkling host.

We rapidly approach, and when we have arrived within a distance comparable with that of its planets, we see that the sun has increased in apparent magnitude, until now it enormously outshines all the other stars, and its rays begin to produce the effect of daylight upon the orbs that they reach. But we are in no danger of mistaking its apparent superiority to its fellow stars for a real one, because we clearly perceive that our nearness alone makes it seem so great and overpowering.

And now we observe that this star that we have drawn near to has attending it a number of minute satellites, faintly shining specks, that circle about it as if charmed, like night-wandering insects, by its splendor. It is manifest to us at the first glance that without the sun these obedient little planets would not exist; it is his attraction that binds them together in a system, and his rays that make them visible to one another in the abyss of space. Although they vary in relative size, yet we observe a striking similarity among them. They are all globular bodies, they all turn upon their axes, they all travel about the sun in the same direction, and their paths all lie very nearly in one plane. Some of them have one or more moons, or satellites, circling about them in imitation of their own revolution about the sun. Their family relationship to one another and to the sun is so evident that it colors our judgment about them as individuals; and when we happen to find, upon closer approach, that one of them, the earth, is covered with vegetation and water and filled with thousands of species of animated creatures, we are disposed to believe, without further examination, that they are all alike in this respect, just as they are all alike in receiving light and heat from the sun.

This preliminary judgment, arising from the evident unity of the planetary system, can only be varied by an examination of its members in detail.

One striking fact that commands our attention as soon as we have entered the narrow precincts of the solar system is the isolation of the sun and its attendants in space. The solar system occupies a disk-shaped, or flat circular, expanse, about 5,580,000,000 miles across and relatively very thin, the sun being in the center. From the sun to the nearest star, or other sun, the distance is approximately five thousand times the entire diameter of the solar system. But the vast majority of the stars are probably a hundred times yet more remote. In other words, if the Solar system be represented by a circular flower-bed ten feet across, the nearest star must be placed at a distance of nine and a half miles, and the great multitude of the stars at a distance of nine hundred miles!

Or, to put it in another way, let us suppose the sun and his planets to be represented by a fleet of ships at sea, all included within a space about half a mile across; then, in order that there might be no shore relatively nearer than the nearest fixed star is to the sun, we should have to place our fleet in the middle of the Pacific Ocean, while the distance of the main shore of the starry universe would be so immense that the whole surface of the earth would be far too small to hold the expanse of ocean needed to represent it!

From these general considerations we next proceed to recall some of the details of the system of worlds amid which we dwell. Besides the earth, the sun has seven other principal planets in attendance. These eight planets fall into two classes—the terrestrial planets and the major, or jovian, planets. The former class comprises Mercury, Venus, the earth, and Mars, and the latter Jupiter, Saturn, Uranus, and Neptune. I have named them all in the order of their distance from the sun, beginning with the nearest.

The terrestrial planets, taking their class name from *terra*, the earth, are relatively close to the sun and comparatively small. The major planets—or the jovian planets, if we give them a common title based upon the name of their chief, Jupiter or Jove—are relatively distant from the sun and are characterized both by great comparative size and slight mean density. The terrestrial planets are all included within a circle, having the sun for a center, about 140,000,000 miles in radius. The space, or gap, between the outermost of them, Mars, and the innermost of the jovian planets, Jupiter, is nearly two and a half times as broad as the entire radius of the circle within which they are included. And not only is the jovian group of planets widely separated from the terrestrial group, but the distances between the orbits of its four members are likewise very great and progressively increasing. Between Jupiter and Saturn is a gap 400,000,000 miles across, and this becomes 900,000,000 miles between Saturn and Uranus, and more than 1,000,000,000 miles between Uranus and Neptune. All of these distances are given in round numbers.

Finally, we come to some very extraordinary worlds—if we can call them worlds at all—the asteroids. They form a third group, characterized by the extreme smallness of its individual members, their astonishing number, and the unusual eccentricities and inclinations of their orbits. They are situated in the gap between the terrestrial and the jovian planets, and about 500 of them have been discovered, while there is reason to think that their real number may be many thousands. The largest of them is less than 500 miles in diameter, and many of those recently discovered may be not more than ten or twenty miles in diameter. What marvelous places of abode such little planets would be if it were possible to believe them inhabited, we shall see more clearly when we come to consider them in their turn. But without regard to the question of habitability, the asteroids will be found extremely interesting.

In the next chapter we proceed to take up the planets for study as individuals, beginning with Mercury, the one nearest the sun.

CHAPTER II

MERCURY, A WORLD OF TWO FACES AND MANY CONTRASTS

Mercury, the first of the other worlds that we are going to consider, fascinates by its grotesqueness, like a piece of Chinese ivory carving, so small is it for its kind and so finished in its eccentric details. In a little while we shall see how singular Mercury is in many of the particulars of planetary existence, but first of all let us endeavor to obtain a clear idea of the actual size and mass of this strange little planet. Compared with the earth it is so diminutive that it looks as if it had been cut out on the pattern of a satellite rather than that of an independent planet. Its diameter, 3,000 miles, only exceeds the moon's by less than one half, while both Jupiter and Saturn, among their remarkable collections of moons, have each at least one that is considerably larger than the planet Mercury. But, insignificant though it be in size, it holds the place of honor, nearest to the sun.

It was formerly thought that Mercury possessed a mass greatly in excess of that which its size would seem to imply, and some estimates, based upon the apparent effect of its attraction on comets, made it equal in mean density to lead, or even to the metal mercury. This led to curious speculations concerning its probable metallic composition, and the possible existence of vast quantities of such heavy elements as gold in the frame of the planet. But more recent, and probably more correct, computations place Mercury third in the order of density among the members of the solar system, the earth ranking as first and Venus as second. Mercury's density is now believed to be less than the earth's in the ratio of 85 to 100. Accepting this estimate, we find that the force of gravity upon the surface of Mercury is only one third as great as upon the surface of the earth—i.e., a body weighing 300 pounds on the earth would weigh only 100 pounds on Mercury.

This is an important matter, because not only the weight of bodies, but the density of the atmosphere and even the nature of its gaseous constituents, are affected by the force of gravity, and if we could journey from world to world, in our bodily form, it would make a great difference to us to find gravity considerably greater or less upon other planets than it is upon our own. This alone might suffice to render some of the planets impossible places of abode for us, unless a decided change were effected in our present physical organization.

One of the first questions that we should ask about a foreign world to which we proposed to pay a visit, would relate to its atmosphere. We should wish to know in advance if it had air and water, and in what proportions and quantities. However its own peculiar inhabitants might be supposed able to dispense with these things, to *us* their presence would be essential, and if we did not find them, even a planet that blazed with gold and diamonds only waiting to be seized would remain perfectly safe from our invasion. Now, in the case of Mercury, some doubt on this point exists.

Messrs. Huggins, Vogel, and others have believed that they found spectroscopic proof of the existence of both air and the vapor of water on Mercury. But the necessary observations are of a very delicate nature, and difficult to make, and some astronomers doubt whether we possess sufficient proof that Mercury has an atmosphere. At any rate, its atmosphere is very rare as compared with the earth's, but we need not, on that account, conclude that Mercury is lifeless. Possibly, in view of certain other peculiarities soon to be explained, a rare atmosphere would be decidedly advantageous.

Being much nearer the sun than the earth is, Mercury can be seen by us only in the same quarter of the sky where the sun itself appears. As it revolves in its orbit about the sun it is visible, alternately, in the evening for a short time after sunset and in the morning for a short time before sunrise, but it can never be seen, as the outer planets are seen, in the mid-heaven or late at night. When seen low in the twilight, at evening or morning, it glows with the brilliance of a bright first-magnitude star, and is a beautiful object, though few casual watchers of the stars ever catch sight of it. When it is nearest the earth and is about to pass between the earth and the sun, it temporarily disappears in the glare of the sunlight; and likewise, when it it is farthest from the earth and passing around in its orbit on the opposite side of the sun, it is concealed by the blinding solar rays. Consequently, except with the instruments of an observatory, which are able to show it in broad day, Mercury is never visible save during the comparatively brief periods of time when it is near its greatest apparent distance east or west from the sun.

The nearer a planet is to the sun the more rapidly it is compelled to move in its orbit, and Mercury, being the nearest to the sun of all the planets, is by far the swiftest footed among them. But its velocity is subject to remarkable variation, owing to the peculiar form of the orbit in which the planet travels. This is more eccentric than the orbit of any other planet, except some of the asteroids. The sun being situated in one focus of the elliptical orbit, when Mercury is at perihelion, or nearest to the sun, its distance from that body is 28,500,000 miles, but when it is at aphelion, or farthest from the sun, its distance is 43,500,000 miles. The difference is no less than 14,000,000 miles! When nearest the sun Mercury darts forward in its orbit at the rate of twenty-nine miles in a second, while when farthest from the sun the speed is reduced to twenty-three miles.

Now, let us return for a moment to the consideration of the wonderful variations in Mercury's distance from the sun, for we shall find that their effects are absolutely startling, and that they alone suffice to mark a wide difference between Mercury and the earth, considered as the abodes of sentient creatures. The total change of distance amounts, as already remarked, to 14,000,000 miles, which is almost half the entire distance separating the planet from the sun at perihelion. This immense variation of distance is emphasized by the rapidity with which it takes place. Mercury's periodic time, i.e., the period required for it to make a single revolution about the sun—or, in other words, the length of its year—is eighty-eight of our days. In just one half of that time, or in about six weeks, it passes from aphelion to perihelion; that is to say, in six weeks the whole change in its distance from the sun takes place. In six weeks Mercury falls 14,000,000 miles—for it *is* a fall, though in a curve instead of a straight line—falls 14,000,000 miles toward the sun! And, as it falls, like any other falling body it gains in speed, until, having reached the perihelion point, its terrific velocity counteracts its approach and it begins to recede. At the end of the next six weeks it once more attains its greatest distance, and turns again to plunge sunward.

Of course it may be said of every planet having an elliptical orbit that between aphelion and perihelion it is falling toward the sun, but no other planet than Mercury travels in an orbit sufficiently eccentric, and approaches sufficiently near to the sun, to give to the mind so vivid an impression of an actual, stupendous fall!

Next let us consider the effects of this rapid fall, or approach, toward the sun, which is so foreign to our terrestrial experience, and so appalling to the imagination.

First, we must remember that the nearer a planet is to the sun the greater is the amount of heat and light that it receives, the variation being proportional to the inverse square of the distance. The earth's distance from the sun being 93,000,000 miles, while Mercury's is only 36,000,000, it follows, to begin with, that Mercury gets, on the average, more than six and a half times as much heat from the sun as the earth does. That alone is enough to make it seem impossible that Mercury can be the home of living forms resembling those of the earth, for imagine the heat of the sun in the middle of a summer's day increased six or seven fold! If there were no mitigating influences, the face of the earth would shrivel as in the blast of a furnace, the very stones would become incandescent, and the oceans would turn into steam.

Still, notwithstanding the tremendous heat poured upon Mercury as compared with that which our planet receives, we can possibly, and for the sake of a clearer understanding of the effects of the varying distance, which is the object of our present inquiry, find a loophole to admit the chance that yet there may be living beings there. We might, for instance, suppose that, owing to the rarity of its atmosphere, the excessive heat was quickly radiated away, or that there was something in the constitution of the atmosphere that greatly modified the effective temperature of the sun's rays. But, having satisfied our imagination on this point, and placed our supposititious inhabitants in the hot world of Mercury, how are we going to meet the conditions imposed by the rapid changes of distance—the swift fall of the planet toward the sun, followed by the equally swift rush away from it? For change of distance implies change of heat and temperature.

It is true that we have a slight effect of this kind on the earth. Between midsummer (of the northern hemisphere) and midwinter our planet draws 3,000,000 miles nearer the sun, but the change occupies six months, and, at the earth's great average distance, the effect of this change is too slight to be ordinarily observable, and only the astronomer is aware of the consequent increase in the apparent size of the sun. It is not to this variation of the sun's distance, but rather to the changes of the seasons, depending on the inclination of the earth's axis, that we owe the differences of temperature that we experience. In other words, the total supply of heat from the sun is not far from uniform at all times of the year, and the variations of temperature depend upon the distribution of that supply between the northern and southern hemispheres, which are alternately inclined sunward.

But on Mercury the supply of solar heat is itself variable to an enormous extent. In six weeks, as we have seen, Mercury diminishes its distance from the sun about one third, which is proportionally ten times as great a change of distance as the earth experiences in six months. The inhabitants of Mercury in those six pregnant weeks see the sun expand in the sky to more than two and a half times its former magnitude, while the solar heat poured upon them swiftly augments from something more than four and a half times to above eleven times the amount received upon the earth! Then, immediately, the retreat of the planet begins, the sun visibly shrinks, as a receding balloon becomes smaller in the eyes of its watchers, the heat falls off as rapidly as it had previously increased, until, the aphelion point being reached, the process is again reversed. And thus it goes on unceasingly, the sun growing and diminishing in the sky, and the heat increasing and decreasing by enormous amounts with astonishing rapidity. It is difficult to imagine any way in which atmospheric influences could equalize the effects of such violent changes, or any adjustments in the physical organization of living beings that could make such changes endurable.

But we have only just begun the story of Mercury’s peculiarities. We come next to an even more remarkable contrast between that planet and our own. During the Paris Exposition of 1889 a little company of astronomers was assembled at the Juvisy observatory of M. Flammarion, near the French capital, listening to one of the most surprising disclosures of a secret of nature that any *savant* ever confided to a few trustworthy friends while awaiting a suitable time to make it public. It was a secret as full of significance as that which Galileo concealed for a time in his celebrated anagram, which, when at length he furnished the key, still remained a riddle, for then it read: “The Mother of the Loves imitates the Shapes of Cynthia,” meaning that the planet Venus, when viewed with a telescope, shows phases like those of the moon. The secret imparted in confidence to the knot of astronomers at Juvisy came from a countryman of Galileo’s, Signor G. V. Schiaparelli, the Director of the Observatory of Milan, and its purport was that the planet Mercury always keeps the same face directed toward the sun. Schiaparelli had satisfied himself, by a careful series of observations, of the truth of his strange announcement, but before giving it to the world he determined to make doubly sure. Early in 1890 he withdrew the pledge of secrecy from his friends and published his discovery.

No one can wonder that the statement was generally received with incredulity, for it was in direct contradiction to the conclusions of other astronomers, who had long believed that Mercury rotated on its axis in a period closely corresponding with that of the earth’s rotation—that is to say, once every twenty-four hours. Schiaparelli’s discovery, if it were received as correct, would put Mercury, as a planet, in a class by itself, and would distinguish it by a peculiarity which had always been recognized as a special feature of the moon, viz., that of rotating on its axis in the same period of time required to perform a revolution in its orbit, and, while this seemed natural enough for a satellite, almost nobody was prepared for the ascription of such eccentric conduct to a planet.

The Italian astronomer based his discovery upon the observation that certain markings visible on the disk of Mercury remained in such a position with reference to the direction of the sun as to prove that the planet’s rotation was extremely slow, and he finally satisfied himself that there was but one rotation in the course of a revolution about the sun. That, of course, means that one side of Mercury always faces toward the sun while the opposite side always faces away from it, and neither side experiences the alternation of day and night, one having perpetual day and the other perpetual night. The older observations, from which had been deduced the long accepted opinion that Mercury rotated, like the earth, once in about twenty-four hours, had also been made upon the markings on the planet’s disk, but these are not easily seen, and their appearances had evidently been misinterpreted.

The very fact of the difficulty of seeing any details on Mercury tended to prevent or delay corroboration of Schiaparelli’s discovery. But there were two circumstances that contributed to the final acceptance of his results. One of these was his well-known experience as an observer and the high reputation that he enjoyed among astronomers, and the other was the development by Prof. George Darwin of the theory of tidal friction in its application to planetary evolution, for this furnished a satisfactory explanation of the manner in which a body, situated as near the sun as Mercury is, could have its axial rotation gradually reduced by the tidal attraction of the sun until it coincided in period with its orbital revolution.

Accepting the accuracy of Schiaparelli's discovery, which was corroborated in every particular in 1896 by Percival Lowell in a special series of observations on Mercury made with his 24-inch telescope at Flagstaff, Arizona, and which has also been corroborated by others, we see at once how important is its bearing on the habitability of the planet. It adds another difficulty to that offered by the remarkable changes of distance from the sun, and consequent variations of heat, which we have already discussed. In order to bring the situation home to our experience, let us, for a moment, imagine the earth fallen into Mercury's dilemma. There would then be no succession of day and night, such as we at present enjoy, and upon which not alone our comfort but perhaps our very existence depends, but, instead, one side of our globe—it might be the Asiatic or the American half—would be continually in the sunlight, and the other side would lie buried in endless night. And this condition, so suggestive of the play of pure imagination, this plight of being a two-faced world, like the god Janus, one face light and the other face dark, must be the actual state of things on Mercury.

There is one interesting qualification. In the case just imagined for the earth, supposing it to retain the present inclination of its axis while parting with its differential rotation, there would be an interchange of day and night once a year in the polar regions. On Mercury, whose axis appears to be perpendicular, a similar phenomenon, affecting not the polar regions but the eastern and western sides of the planet, is produced by the extraordinary eccentricity of its orbit. As the planet alternately approaches and recedes from the sun its orbital velocity, as we have already remarked, varies between the limits of twenty-three and thirty-five miles per second, being most rapid at the point nearest the sun. But this variation in the speed of its revolution about the sun does not, in any manner, affect the rate of rotation on its axis. The latter is perfectly uniform and just fast enough to complete one axial turn in the course of a single revolution about the sun. The accompanying figure may assist the explanation.

Diagram showing that, owing to the Eccentricity of its Orbit, and its Varying Velocity, Mercury, although making but One Turn on its Axis in the Course of a Revolution about the Sun, nevertheless experiences on Parts of its Surface the Alternation of Day and Night.

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Let us start with Mercury in perihelion at the point *A*. The little cross on the planet stands exactly under the sun and in the center of the illuminated hemisphere. The large arrows show the direction in which the planet travels in its revolution about the sun, and the small curved arrows the direction in which it rotates on its axis. Now, in moving along its orbit from *A* to *B* the planet, partly because of its swifter motion when near the sun, and partly because of the elliptical nature of the orbit, traverses a greater angular interval with reference to the sun than the cross, moving with the uniform rotation of the planet on its axis, is able to traverse in the same time. As drawn in the diagram, the cross has moved through exactly ninety degrees, or one right angle, while the planet in its orbit has moved through considerably more than a right angle. In consequence of this gain of the angle of revolution upon the angle of rotation, the cross at *B* is no longer exactly under the sun, nor in the center of the illuminated hemisphere. It appears to have shifted its position toward the west, while the hemispherical cap of sunshine has slipped eastward over the globe of the planet.

In the next following section of the orbit the planet rotates through another right angle, but, owing to increased distance from the sun, the motion in the orbit now becomes slower until, when the planet arrives at aphelion, *C*, the angular difference disappears and the cross is once more just under the sun. On returning from aphelion to perihelion the same phenomena recur in reverse order and the line between day and night on the planet first shifts westward, attaining its limit in that respect at *D*, and then, at perihelion, returns to its original position.

Now, if we could stand on the sunward hemisphere of Mercury what, to our eyes, would be the effect of this shifting of the sun's position with regard to a fixed point on the planet's surface? Manifestly it would cause the sun to describe a great arc in the sky, swinging to and fro, in an east and west line, like a pendulum bob, the angular extent of the swing being a little more than forty-seven degrees, and the time required for the sun to pass from its extreme eastern to its extreme western position and back again being eighty-eight days. But, owing to the eccentricity of the orbit, the sun swings much faster toward the east than toward the west, the eastward motion occupying about thirty-seven days and the westward motion about fifty-one days.

The Regions of Perpetual Day, Perpetual Night, and Alternate Day and Night on Mercury. In the Left-Hand View the Observer looks at the Planet in the Plane of its Equator; in the Right-Hand View he looks down on its North Pole.

THE REGIONS OF PERPETUAL DAY, PERPETUAL NIGHT, AND ALTERNATE DAY AND NIGHT ON MERCURY. IN THE LEFT-HAND VIEW THE OBSERVER LOOKS AT THE PLANET IN THE PLANE OF ITS EQUATOR; IN THE RIGHT-HAND VIEW HE LOOKS DOWN ON ITS NORTH POLE..

Another effect of the libratory motion of the sun as seen from Mercury is represented in the next figure, where we have a view of the planet showing both the day and the night hemisphere, and where we see that between the two there is a region upon which the sun rises and sets once every eighty-eight days. There are, in reality, two of these lune-shaped regions, one at the east and the other at the west, each between 1,200 and 1,300 miles broad at the equator. At the sunward edge of these regions, once in eighty-eight days, or once in a Mercurial year, the sun rises to an elevation of forty-seven degrees, and then descends again straight to the horizon from which it rose; at the nightward edge, once in eighty-eight days, the sun peeps above the horizon and quickly sinks from sight again. The result is that, neglecting the effects of atmospheric refraction, which would tend to expand the borders of the domain of sunlight, about one quarter of the entire surface of Mercury is, with regard to day and night, in a condition resembling that of our polar regions, where there is but one day and one night in the course of a year—and on Mercury a year is eighty-eight days. One half of the remaining three quarters of the planet’s surface is bathed in perpetual sunshine and the other half is a region of eternal night.

And now again, what of life in such a world as that? On the night side, where no sunshine ever penetrates, the temperature must be extremely low, hardly greater than the fearful cold of open space, unless modifying influences beyond our ken exist. It is certain that if life flourishes there, it must be in such forms as can endure continual darkness and excessive cold. Some heat would be carried around by atmospheric circulation from the sunward side, but not enough, it would seem, to keep water from being perpetually frozen, or the ground from being baked with unrelaxing frost. It is for the imagination to picture underground dwellings, artificial sources of heat, and living forms suited to unearthlike environment.

What would be the mental effects of perpetual night upon a race of intelligent creatures doomed to that condition? Perhaps not quite so grievous as we are apt to think. The constellations in all their splendor would circle before their eyes with the revolution of their planet about the sun, and with the exception of the sun itself—which they could see by making a journey to the opposite hemisphere—all the members of the solar system would pass in succession through their mid-heaven, and two of them would present themselves with a magnificence of planetary display unknown on the earth. Venus, when in opposition under the most favorable circumstances, is scarcely more than 24,000,000 miles from Mercury, and, showing herself at such times with a fully illuminated disk—as, owing to her position within the orbit of the earth, she never can do when at her least distance from us—she must be a phenomenon of unparalleled beauty, at least four times brighter than we ever see her, and capable, of course, of casting a strong shadow.

The earth, also, is a splendid star in the midnight sky of Mercury, and the moon may be visible to the naked eye as a little attendant circling about its brilliant master. The outer planets are slightly less conspicuous than they are to us, owing to increase of distance.

The revolution of the heavens as seen from the night side of Mercury is quite different in period from that which we are accustomed to, although the apparent motion is in the same direction, viz., from east to west. The same constellations remain above the horizon for weeks at a time, slowly moving westward, with the planets drifting yet more slowly, but at different rates, among them; the nearer planets, Venus and the earth, showing the most decided tendency to loiter behind the stars.

On the side where eternal sunlight shines the sky of Mercury contains no stars. Forever the pitiless blaze of day; forever,

“All in a hot and copper sky
The bloody sun at noon.”

As it is difficult to understand how water can exist on the night hemisphere, except in the shape of perpetual snow and ice, so it is hard to imagine that on the day hemisphere water can ever be precipitated from the vaporous form. In truth, there can be very little water on Mercury even in the form of vapor, else the spectroscope would have given unquestionable evidence of its presence. Those who think that Mercury is entirely waterless and almost, if not quite, airless may be right. In these respects it would then resemble the moon, and, according to some observers, it possesses another characteristic lunar feature in the roughening of its surface by what seem to be innumerable volcanic craters.

But if we suppose Mercury to possess an atmosphere much rarer than that of the earth, we may perceive therein a possible provision against the excessive solar heat to which it is subjected, since, as we see on high mountains, a light air permits a ready radiation of heat, which does not become stored up as in a denser atmosphere.

As the sun pours its heat without cessation upon the day hemisphere the warmed air must rise and flow off on all sides into the night hemisphere, while cold air rushes in below, to take its place, from the region of frost and darkness. The intermediate areas, which see the sun part of the time, as explained above, are perhaps the scene of contending winds and tempests, where the moisture, if there be any, is precipitated, through the rapid cooling of the air, in whelming floods and wild snow-storms driven by hurrying blasts from the realm of endless night.

Enough seems now to have been said to indicate clearly the hopelessness of looking for any analogies between Mercury and the earth which would warrant the conclusion that the former planet is capable of supporting inhabitants or forms of life resembling those that swarm upon the latter. If we would still believe that Mercury is a habitable globe we must depend entirely upon the imagination for pictures of creatures able to endure its extremes of heat and cold, of light and darkness, of instability, swift vicissitude, and violent contrast.

In the next chapter we shall study a more peaceful and even-going world, yet one of great brilliancy, which possesses some remarkable resemblances to the earth, as well as some surprising divergences from it.

CHAPTER III

VENUS, THE TWIN OF THE EARTH

We come now to a planet which seems, at the first glance, to afford a far more promising outlook than Mercury does for the presence of organic life forms bearing some resemblance to those of the earth. One of the strongest arguments for regarding Venus as a world much like ours is based upon its remarkable similarity to the earth in size and mass, because thus we are assured that the force of gravity is practically the same upon the two planets, and the force of gravity governs numberless physical phenomena of essential importance to both animal and vegetable life. The mean diameter of the earth is 7,918 miles; that of Venus is 7,700 miles. The difference is so slight that if the two planets were suspended side by side in the sky, at such a distance that their disks resembled that of the full moon, the eye would notice no inequality between them.

The mean density of Venus is about nine tenths of that of the earth, and the force of gravity upon its surface is in the ratio of about 85 to 100 as compared to its force on the surface of the earth. A man removed to Venus would, consequently, find himself perceptibly lighter than he was at home, and would be able to exert his strength with considerably greater effect than on his own planet. But the difference would amount only to an agreeable variation from accustomed conditions, and would not be productive of fundamental changes in the order of nature.

Being, like Mercury, nearer to the sun than the earth is, Venus also is visible to us only in the morning or the evening sky. But her distance from the sun, slightly exceeding 67,000,000 miles, is nearly double that of Mercury, so that, when favorably situated, she becomes a very conspicuous object, and, instead of being known almost exclusively by astronomers, she is, perhaps, the most popular and most admired of all the members of the planetary system, especially when she appears in the charming rôle of the “evening star.” As she emerges periodically from the blinding glare of the sun’s immediate neighborhood and begins to soar, bright as an electric balloon, in the twilight, she commands all eyes and calls forth exclamations of astonishment and admiration by her singular beauty. The intervals between her successive reappearances in the evening sky, measured by her synodic period of 584 days, are sufficiently long to give an element of surprise and novelty to every return of so dazzling a phenomenon.

Even the light of the full moon silvering the tree tops does not exercise greater enchantment over the mind of the contemplative observer. In either of her rôles, as morning or as evening star, Venus has no rival. No fixed star can for an instant bear comparison with her. What she lacks in vivacity of light—none of the planets twinkles, as do all of the true stars—is more than compensated by the imposing size of her gleaming disk and the striking beauty of her clear lamplike rays. Her color is silvery or golden, according to the state of the atmosphere, while the distinction of her appearance in a dark sky is so great that no eye can resist its attraction, and I have known an unexpected glimpse of Venus to put an end to an animated conversation and distract, for a long time, the attention of a party of ladies and gentlemen from the social occupation that had brought them together.

As a telescopic object Venus is exceedingly attractive, even when considered merely from the point of view of simple beauty. Both Mercury and Venus, as they travel about the sun, exhibit phases like those of the moon, but Venus, being much larger and much nearer to the earth than Mercury, shows her successive phases more effectively, and when she shines as a thin crescent in the morning or evening twilight, only a very slight magnifying power is required to show the sickle form of her disk.

A remarkable difference between Venus and Mercury comes out as soon as we examine the shape of the former’s orbit. Venus’s mean distance from the sun is 67,200,000 miles, and her orbit is so nearly a circle, much more nearly than that of any other planet, that in the course of a revolution her distance from the sun varies less than a million miles. The distance of the earth varies 3,000,000 miles, and that of Mercury 14,000,000. Her period of revolution, or the length of her year, is 225 of our days. When she comes between the sun and the earth she approaches us nearer than any other planet ever gets, except the asteroid Eros, her distance at such times being 26,000,000 miles, or about one hundred and ten times the distance of the moon.

Being nearer to the sun in the ratio of 67 to 93, Venus receives almost twice as much solar light and heat as we get, but less than one third as much as Mercury gets. There is reason to believe that her axis, instead of being considerably inclined, like that of the earth, is perpendicular to the plane of her orbit. Thus Venus introduces to us another novelty in the economy of worlds, for with a perpendicular axis of rotation she can have no succession of seasons, no winter and summer flitting, one upon the other’s heels, to and fro between the northern and southern hemispheres; but, on the contrary, her climatic conditions must be unchangeable, and, on any particular part of her surface, except for local causes of variation, the weather remains the same the year around. So, as far as temperature is concerned, Venus may have two regions of perpetual winter, one around each pole; two belts of perpetual spring in the upper middle latitudes, one on each side of the equator; and one zone of perpetual summer occupying the equatorial portion of the planet. But, of course, these seasonal terms do not strictly apply to Venus, in the sense in which we employ them on the earth, for with us spring is characterized rather by the change in the quantity of heat and other atmospheric conditions that it witnesses than by a certain fixed and invariable temperature.

To some minds it may appear very undesirable, from the point of view of animate existences, that there should be no alternation of seasons on the surface of a planet, but, instead, fixed conditions of climate; yet it is not clear that such a state of affairs might not be preferable to that with which we are familiar. Even on the earth, we find that tropical regions, where the seasonal changes are comparatively moderate, present many attractions and advantages in contrast with the violent and often destructive vicissitudes of the temperate zones, and nature has shown us, within the pale of our own planet, that she is capable of bringing forth harvests of fruit and grain without the stimulus of alternate frost and sunshine.

Even under the reign of perpetual summer the fields and trees find time and opportunity to rest and restore their productive forces.

The circularity of Venus’s orbit, and the consequently insignificant change in the sun’s distance and heating effect, are other elements to be considered in estimating the singular constancy in the operation of natural agencies upon that interesting planet, which, twin of the earth though it be in stature, is evidently not its twin in temperament.

And next as to the all-important question of atmosphere. In what precedes, the presence of an atmosphere has been assumed, and, fortunately, there is very convincing evidence, both visual and spectroscopic, that Venus is well and abundantly supplied with air, by which it is not meant that Venus's air is precisely like the mixture of oxygen and nitrogen, with a few other gases, which we breathe and call by that name. In fact, there are excellent reasons for thinking that the atmosphere of Venus differs from the earth's quite as much as some of her other characteristics differ from those of our planet. But, however it may vary from ours in constitution, the atmosphere of Venus contains water vapor, and is exceedingly abundant. Listen to Professor Young:

“Its [Venus's] atmosphere is probably from one and a half to two times as extensive and as dense as our own, and the spectroscope shows evidence of the presence of water vapor in it.”

And Prof. William C. Pickering, basing his statement on the result of observations at the mountain observatory of Arequipa, says: “We may feel reasonably certain that at the planet's [Venus's] surface the density of its atmosphere is many times that of our own.”

We do not have to depend upon the spectroscope for evidence that Venus has a dense atmosphere, for we can, in a manner, *see* her atmosphere, in consequence of its refractive action upon the sunlight that strikes into it near the edge of the planet's globe. This illumination of Venus's atmosphere is witnessed both when she is nearly between the sun and the earth, and when, being exactly between them, she appears in silhouette against the solar disk. During a transit of this kind, in 1882, many observers, and the present writer was one, saw a bright atmospheric bow edging a part of the circumference of Venus when the planet was moving upon the face of the sun—a most beautiful and impressive spectacle.

Even more curious is an observation made in 1866 by Prof. C.S. Lyman, of Yale College, who, when Venus was very near the sun, saw her atmosphere *in the form of a luminous ring*. A little fuller explanation of this appearance may be of interest.

When approaching inferior conjunction—i.e., passing between the earth and sun—Venus appears, with a telescope, in the shape of a very thin crescent. Professor Lyman watched this crescent, becoming narrower day after day as it approached the sun, and noticed that its extremities gradually extended themselves beyond the limits of a semicircle, bending to meet one another on the opposite side of the invisible disk of the planet, until, at length, they did meet, and he beheld a complete ring of silvery light, all that remained visible of the planet Venus! The ring was, of course, the illuminated atmosphere of the planet refracting the sunlight on all sides around the opaque globe.

In 1874 M. Flammarion witnessed the same phenomenon in similar circumstances. One may well envy those who have had the good fortune to behold this spectacle—to actually see, as it were, the air that the inhabitants of another world are breathing and making resonant with all the multitudinous sounds and voices that accompany intelligent life. But perhaps some readers will prefer to think that even though an atmosphere is there, there is no one to breathe it.

Venus's Atmosphere seen as a Ring of Light.

Venus's Atmosphere seen as a Ring of Light.

As the visibility of Venus's atmosphere is unparalleled elsewhere in the solar system, it may be worth while to give a graphic illustration of it. In the accompanying figure the planet is represented at three successive points in its advance toward inferior conjunction. As it approaches conjunction it slowly draws nearer the earth, and its apparent diameter consequently increases. At *A* a large part of the luminous crescent is composed of the planet's surface reflecting the sunshine; at *B* the ratio of the reflecting surface to the illuminated atmosphere has diminished, and the latter has extended, like the curved arms of a pair of calipers, far around the unilluminated side of the disk; at *C* the atmosphere is illuminated all around by the sunlight coming through it from behind, while the surface of the planet has passed entirely out of the light—that is to say, Venus has become an invisible globe embraced by a circle of refracted sunshine.

We return to the question of life. With almost twice as much solar heat and light as we have, and with a deeper and denser atmosphere than ours, it is evident, without seeking other causes of variation, that the conditions of life upon Venus are notably different from those with which we are acquainted. At first sight it would seem that a dense atmosphere, together with a more copious supply of heat, might render the surface temperature of Venus unsuitable for organic life as we understand it. But so much depends upon the precise composition of the atmosphere and upon the relative quantities of its constituents, that it will not do to pronounce a positive judgment in such a case, because we lack information on too many essential points.

Experiment has shown that the temperature of the air varies with changes in the amount of carbonic acid and of water vapor that it contains. It has been suggested that in past geologic ages the earth's atmosphere was denser and more heavily charged with vapors than it is at present; yet even then forms of life suited to their environment existed, and from those forms the present inhabitants of our globe have been developed. There are several lines of reasoning which may be followed to the conclusion that Venus, as a life-bearing world, is younger than the earth, and, according to that view, we are at liberty to imagine our beautiful sister planet as now passing through some such period in its history as that at which the earth had arrived in the age of the carboniferous forests, or the age of the gigantic reptiles who ruled both land and sea.

But, without making any assumptions as to the phase of evolution which life may have attained on Venus, it is also possible to think that the planet's thick shell of air, with its abundant vapors, may serve as a shield against the excessive solar radiation. Venus is extraordinarily brilliant, its reflective power being greatly in excess of Mercury's, and it has often been suggested that this may be due to the fact that a large share of the sunlight falling upon it is turned back before reaching the planet's surface, being reflected both from the atmosphere itself and from vast layers of clouds.

Even when viewed with the most powerful telescopes and in the most favoring circumstances, the features of Venus's surface are difficult to see, and generally extremely difficult. They consist of faint shadowy markings, indefinite in outline, and so close to the limit of visibility that great uncertainty exists not only as to their shape and their precise location upon the planet, but even as to their actual existence. No two observers have represented them exactly alike in drawings of the planet, and, unfortunately, photography is as yet utterly unable to deal with them. Mr. Percival Lowell, in his special studies of Venus in 1896, using a 24-inch telescope of great excellence, in the clear and steady air of Arizona, found delicate spokelike streaks radiating from a rounded spot like a hub, and all of which, in his opinion, were genuine and definite markings on the planet's surface. But others, using larger telescopes, have failed to perceive the shapes and details depicted by Mr. Lowell, and some are disposed to ascribe their appearances to Venus's atmosphere. Mr. Lowell himself noticed that the markings seemed to have a kind of obscuring veil over them.

In short, all observers of Venus agree in thinking that her atmosphere, to a greater or less extent, serves as a mask to conceal her real features, and the possibilities of so extensive an atmosphere with reference to an adjustment of the peculiar conditions of the planet to the requirements of life upon it, are almost unlimited. If we could accurately analyze that atmosphere we would have a basis for more exact conclusions concerning Venus's habitability.

But the mere existence of the atmosphere is, in itself, a strong argument for the habitability of the planet, and as to the temperature, we are really not compelled to imagine special adaptations by means of which it may be brought into accord with that prevailing upon the earth. As long as the temperature does not rise to the *destructive* point, beyond which our experience teaches that no organic life can exist, it may very well attain an elevation that would mean extreme discomfort from our point of view, without precluding the existence of life even in its terrestrial sense.

And would it not be unreasonable to assume that vital phenomena on other planets must be subject to exactly the same limitations that we find circumscribing them in our world? That kind of assumption has more than once led us far astray even in dealing with terrestrial conditions.

It is not so long ago, for instance, since life in the depths of the sea was deemed to be demonstrably impossible. The bottom of the ocean, we were assured, was a region of eternal darkness and of frightful pressure, wherein no living creatures could exist. Yet the first dip of the deep-sea trawl brought up animals of marvelous delicacy of organization, which, although curiously and wonderfully adapted to live in a compressed liquid, collapsed when lifted into a lighter medium, and which, despite the assumed perpetual darkness of their profound abode, were adorned with variegated colors and furnished with organs of phosphorescence whereby they could create for themselves all the light they needed.

Even the fixed animals of the sea, growing, like plants, fast to the rocks, are frequently vivid with living light, and there is a splendid suggestion of nature's powers of adaptation, which may not be entirely inapplicable to the problems of life on strange planets, in Alexander Agassiz's statement that species of sea animals, living below the depths to which sunlight penetrates, "may dwell in total darkness and be illuminated at times merely by the movements of abyssal fishes through the forests of phosphorescent alcyonarians."

In attempting to judge the habitability of a planet such as Venus we must first, as far as possible, generalize the conditions that govern life and restrict its boundaries.

On the earth we find animated existence confined to the surface of the crust of the globe, to the lower and denser strata of the atmosphere, and to the film of water that constitutes the oceans. It does not exist in the heart of the rocks forming the body of the planet nor in the void of space surrounding it outside the atmosphere. As the earth condensed from the original nebula, and cooled and solidified, a certain quantity of matter remained at its surface in the form of free gases and unstable compounds, and, within the narrow precincts where these things were, lying like a thin shell between the huge inert globe of permanently combined elements below, and the equally unchanging realm of the ether above, life, a phenomenon depending upon ceaseless changes, combinations and recombinations of chemical elements in unstable and temporary union, made its appearance, and there only we find it at the present time.

It is because air and water furnish the means for the continual transformations by which the bodies of animals and plants are built up and afterward disintegrated and dispersed, that we are compelled to regard their presence as prerequisites to the existence, on any planet, of life in any of the forms in which we are acquainted with it. But if we perceive that another world has an atmosphere, and that there is water vapor in its atmosphere—both of which conditions are fulfilled by Venus—and if we find that that world is bathed in the same sunshine that stimulates the living forces of our planet, even though its quantity or intensity may be different, then it would seem that we are justified in averring that the burden of proof rests upon those who would deny the capability of such a world to support inhabitants.

The generally accepted hypothesis of the origin of the solar system leads us to believe that Venus has experienced the same process of evolution as that which brought the earth into its present condition, and we may fairly argue that upon the rocky shell of Venus exists a region where chemical combinations and recombinations like those on the surface of the earth are taking place. It is surely not essential that the life-forming elements should exist in exactly the same states and proportions as upon the earth; it is enough if some of them are manifestly present. Even on the earth these things have undergone much variation in the course of geological history, coincidently with the development of various species of life. Just at present the earth appears to have reached a stage where everything contributes to the maintenance of a very high organization in both the animal and vegetable kingdoms.

So each planet that has attained the habitable stage may have a typical adjustment of temperature and atmospheric constitution, rendering life possible within certain limits peculiar to that planet, and to the special conditions prevailing there. Admitting, as there is reason for doing, that different planets may be at different stages of development in the geological and biological sense, we should, of course, not expect to find them inhabited by the same living species. And, since there is also reason to believe that no two planets upon arriving at the same stage of evolution as globes would possess identical gaseous surroundings, there would naturally be differences between their organic life forms notwithstanding the similarity of their common phase of development in other respects. Thus a departure from the terrestrial type in the envelope of gases covering a planet, instead of precluding life, would only tend to vary its manifestations.

After all, why should the intensity of the solar radiation upon Venus be regarded as inimical to life? The sunbeams awaken life.

It is not impossible that relative nearness to the sun may be an advantage to Venus from the biologic point of view. She gets less than one third as much heat as Mercury receives on the average, and she gets it with almost absolute uniformity. At aphelion Mercury is about two and four tenths times hotter than Venus; then it rushes sunward, and within forty-four days becomes six times hotter than Venus. In the meantime the temperature of the latter, while high as compared with the earth's, remains practically unchanged. Not only may Mercury's temperature reach the destructive point, and thus be too high for organic life, but Mercury gets nothing with either moderation or constancy. It is a world both of excessive heat and of violent contrasts of temperature. Venus, on the other hand, presents an unparalleled instance of invariableness and uniformity. She may well be called the favorite of the sun, and, through the advantages of her situation, may be stimulated by him to more intense vitality than falls to the lot of the earth.

It is open, at least to the writers of the interplanetary romances now so popular, to imagine that on Venus, life, while encompassed with the serenity that results from the circular form of her orbit, and the unchangeableness of her climates, is richer, warmer, more passionate, more exquisite in its forms and more fascinating in its experiences, keener of sense, capable of more delicious joys, than is possible to it amid the manifold inclemencies of the colder earth.

We have seen that there is excellent authority for saying that Venus's atmosphere is from one and a half to two times as dense and as extensive as ours. Here is an interesting suggestion of aerial possibilities for her inhabitants. If man could but fly, how would he take to himself wings and widen his horizons along with the birds! Give him an atmosphere the double in density of that which now envelopes him, take off a little of his weight, thereby increasing the ratio of his strength and activity, put into his nervous system a more puissant stimulus from the life-giving sun, and perchance he *would* fly.

Well, on Venus, apparently, these very conditions actually exist. How, then, do intellectual creatures in the world of Venus take wing when they choose? Upon what spectacle of fluttering pinions afloat in iridescent air, like a Raphael dream of heaven and its angels, might we not look down if we could get near enough to our brilliant evening star to behold the intimate splendors of its life?

As Venus herself would be the most brilliant member of the celestial host to an observer stationed on the night side of Mercury, so the earth takes precedence in the midnight sky of Venus. For the inhabitants of Venus Mercury is a splendid evening and morning star only, while the earth, being an outer planet, is visible at times in that part of the sky which is directly opposite to the place of the sun. The light reflected from our planet is probably less dazzling than that which Venus sends to us, both because, at our greater distance, the sunlight is less intense, and because our rarer atmosphere reflects a smaller proportion of the rays incident upon it. But the earth is, after all, a more brilliant phenomenon seen from Venus than the latter is seen from the earth, for the reason that the entire illuminated disk of the earth is presented toward our sister planet when the two are at their nearest point of approach, whereas, at that time, the larger part of the surface of Venus that is turned earthward has no illumination, while the illuminated portion is a mere crescent.

Owing, again, to the comparative rarity of the terrestrial atmosphere, it is probable that the inhabitants of Venus—assuming their existence—enjoy a superb view of the continents, oceans, polar snows, and passing clouds that color and variegate the face of the earth. Our astronomers can study the full disk of Venus only when she is at her greatest distance, and on the opposite side of the sun from us, where she is half concealed in the glare. The astronomers of Venus, on the other hand, can study the earth under the most favorable conditions of observation—that is to say, when it is nearest to them and when, being in opposition to the sun, its whole disk is fully illuminated. In fact, there is no planet in the entire system which enjoys an outlook toward a sister world comparable with that which Venus enjoys with regard to the earth. If there be astronomers upon Venus, armed with telescopes, it is safe to guess that they possess a knowledge of the surface of the earth far exceeding in minuteness and accuracy the knowledge that we possess of the features of any heavenly body except the moon. They must long ago have been able to form definite conclusions concerning the meteorology and the probable habitability of our planet.

It certainly tends to increase our interest in Venus when, granting that she is inhabited, we reflect upon the penetrating scrutiny of which the earth may be the object whenever Venus—as happens once every 584 days—passes between us and the sun. The spectacle of our great planet, glowing in its fullest splendor in the midnight sky, pied and streaked with water, land, cloud, and snow, is one that might well excite among the astronomers of another world, so fortunately placed to observe it, an interest even greater than that which the recurrence of total solar eclipses occasions upon the earth. For the inhabitants of Venus the study of the earth must be the most absorbing branch of observational astronomy, and the subject, we may imagine, of numberless volumes of learned memoirs, far exceeding in the definiteness of their conclusions the books that we have written about the physical characteristics of other members of the solar system. And, if we are to look for attempts on the part of the inhabitants of other worlds to communicate with us by signals across the ether, it would certainly seem that Venus is the most likely source of such efforts, for from no other planet can those features of the earth that give evidence of its habitability be so clearly discerned. Of one thing it would seem we may be certain: if Venus has intellectual inhabitants they possess far more convincing evidence of our existence than we are likely ever to have of theirs.

In referring to the view of the earth from Mercury it was remarked that the moon is probably visible to the naked eye. From Venus the moon is not only visible, but conspicuous, to the naked eye, circling about the earth, and appearing at times to recede from it to a distance of about half a degree—equal to the diameter of the full moon as we see it. The disk of the earth is not quite four times greater in diameter than that of the moon, and nowhere else in the solar system is there an instance in which two bodies, no more widely different in size than are the moon and the earth, are closely linked together. The moons of the other planets that possess satellites are relatively so small that they appear in the telescope as mere specks beside their primaries, but the moon is so large as compared with the earth that the two must appear, as viewed from Venus, like a double planet. To the naked eye they may look like a very wide and brilliant double star, probably of contrasted colors, the moon being silvery white and the earth, perhaps, now of a golden or reddish tinge and now green or blue, according to the part of its surface turned toward Venus, and according, also, to the season that chances to be reigning over that part.

Such a spectacle could not fail to be of absorbing interest, and we can not admit the possibility of intelligent inhabitants on Venus without supposing them to watch the motions of the moon and the earth with the utmost intentness. The passage of the moon behind and in front of the earth, and its eclipses when it goes into the earth's shadow, could be seen without the aid of telescopes, while, with such instruments, these phenomena would possess the highest scientific interest and importance.

Because the earth has a satellite so easily observable, the astronomers of Venus could not remain ignorant of the exact mass of our planet, and in that respect they would outstrip us in the race for knowledge, since, on account of the lack of a satellite attending Venus, we have been able to do no more than make an approximate estimate of her mass.

With telescopes, too, in the case of a solar eclipse occurring at the time of the earth's opposition, they could see the black spot formed by the shadow of the moon, where the end of its cone moved across the earth like the point of an invisible pencil, and could watch it traversing continents and oceans, or thrown out in bold contrast upon the white background of a great area of clouds. Indeed, the phenomena which our globe and its satellite present to Venus must be so varied and wonderful that one might well wish to visit that planet merely for the sake of beholding them.

Thus far we have found so much of brilliant promise in the earth's twin sister that I almost hesitate to approach another phase of the subject which may tend to weaken the faith of some readers in the habitability of Venus. It may have been observed that heretofore nothing has been said as to the planet's rotation period, but, without specifically mentioning it, I have tacitly assumed the correctness of the generally accepted period of about twenty-four hours, determined by De Vico and other observers. This period, closely accordant with the earth's, is, as far as it goes, another argument for the habitability of Venus.

But now it must be stated that no less eminent an authority than Schiaparelli holds that Venus, as well as Mercury, makes but a single turn on its axis in the course of a revolution about the sun, and, consequently, is a two-faced world, one side staring eternally at the sun and the other side wearing the black mask of endless night.

Schiaparelli made this announcement concerning Venus but a few weeks after publishing his discovery of Mercury's peculiar rotation. He himself appears to be equally confident in both cases of the correctness of his conclusions and the certainty of his observation. As with Mercury, several other observers have corroborated him, and particularly Percival Lowell in this country. Mr. Lowell, indeed, seems unwilling to admit that any doubt can be entertained. Nevertheless, very grave doubt is entertained, and that by many, and probably by the majority, of the leading professional astronomers and observers. In fact, some observers of great ability, equipped with powerful instruments, have directly contradicted the results of Schiaparelli and his supporters.

The reader may ask: "Why so readily accept Schiaparelli's conclusions with regard to Mercury while rejecting them in the case of Venus?"

The reply is twofold. In the first place the markings on Venus, although Mr. Lowell sketched them with perfect confidence in 1896, are, by the almost unanimous testimony of those who have searched for them with telescopes, both large and small, extremely difficult to see, indistinct in outline, and perhaps evanescent in character. The sketches of no two observers agree, and often they are remarkably unlike. The fact has already been mentioned that Mr. Lowell noticed a kind of veil partially obscuring the markings, and which he ascribed, no doubt correctly, to the planet’s atmosphere. But he thinks that, notwithstanding the atmospheric veil, the markings noted by him were unquestionably permanent features of the planet’s real surface. Inasmuch, however, as his drawings represent things entirely different from what others have seen, there seems to be weight in the suggestion that the radiating bands and shadings noticed by him were in some manner illusory, and perhaps of atmospheric origin.

If the markings were evidently of a permanent nature and attached to the solid shell of the planet, and if they were of sufficient distinctness to be seen in substantially the same form by all observers armed with competent instruments, then whatever conclusion was drawn from their apparent motion as to the period of the planet’s rotation would have to be accepted. In the case of Mercury the markings, while not easily seen, appear to be sufficiently distinct to afford confidence in the result of observations based upon them, but Venus’s markings have been represented in so many different ways that it seems advisable to await more light before accepting any extraordinary, and in itself improbable, conclusion based upon them.

It should also be added that in 1900 spectroscopic observations by Belopolski at Pulkova gave evidence that Venus really rotates rapidly on her axis, in a period probably approximating to the twenty-four hours of the earth’s rotation, thus corroborating the older conclusions.

Belopolski’s observation, it may be remarked, was based upon what is known as the Doppler principle, which is employed in measuring the motion of stars in the line of sight, and in other cases of rapidly moving sources of light. According to this principle, when a source of light, either original or reflected, is approaching the observer, the characteristic lines in its spectrum are shifted toward the blue end, and when it is retreating from the observer the lines are shifted toward the red end. Now, in the case of a planet rotating rapidly on its axis, it is clear that if the observer is situated in, or nearly in, the plane of the planet’s equator, one edge of its disk will be approaching his eye while the opposite edge is retreating, and the lines in the spectrum of a beam of light from the advancing edge will be shifted toward the blue, while those in the spectrum of the light coming from the retreating edge will be shifted toward the red. And, by carefully noting the amount of the shifting, the velocity of the planet’s rotation can be computed. This is what was done by Belopolski in the case of Venus, with the result above noted.

Secondly, the theory that Venus rotates but once in the course of a revolution finds but slight support from the doctrine of tidal friction, as compared with that which it receives when applied to Mercury. The effectiveness of the sun’s attraction in slowing down the rotation of a planet through the braking action of the tides raised in the body of the planet while it is yet molten or plastic, varies inversely as the sixth power of the planet’s distance. For Mercury this effectiveness is nearly three hundred times as great as it is for the earth, while for Venus it is only seven times as great. While we may admit, then, that Mercury, being relatively close to the sun and subject to an enormous braking action, lost rotation until—as occurred for a similar reason to the moon under the tidal attraction of the earth—it ended by keeping one face always toward its master, we are not prepared to make the same admission in the case of Venus, where the effective force concerned is comparatively so slight.

It should be added, however, that no certain evidence of polar compression in the outline of Venus’s disk has ever been obtained, and this fact would favor the theory of a very slow rotation because a plastic globe in swift rotation has its equatorial diameter increased and its polar diameter diminished. If Venus were as much flattened at the poles as the earth is, it would seem that the fact could not escape detection, yet the necessary observations are very difficult, and Venus is so brilliant that her light increases the difficulty, while her transits across the sun, when she can be seen as a round black disk, are very rare phenomena, the latest having occurred in 1874 and 1882, and the next not being due until 2004.

Upon the whole, probably the best method of settling the question of Venus’s rotation is the spectroscopic method, and that, as we saw, has already given evidence for the short period.

Even if it were established that Venus keeps always the same face to the sun, it might not be necessary to abandon altogether the belief that she is habitable, although, of course, the obstacles to that belief would be increased. Venus’s orbit being so nearly circular, and her orbital motion so nearly invariable, she has but a very slight libration with reference to the sun, and the east and west lunes on her surface, where day and night would alternate once in her year of 225 days, would be so narrow as to be practically negligible.

But, owing to her extensive atmosphere, there would be a very broad band of twilight on Venus, running entirely around the planet at the inner edge of the light hemisphere. What the meteorological conditions within this zone would be is purely a matter of conjecture. As in the case of Mercury, we should expect an interchange of atmospheric currents between the light and dark sides of the planet, the heated air rising under the influence of the unsetting sun in one hemisphere, and being replaced by an indraught of cold air from the other. The twilight band would probably be the scene of atmospheric conflicts and storms, and of immense precipitation, if there were oceans on the light hemisphere to charge the air with moisture.

It has been suggested that ice and snow might be piled in a vast circle of glaciers, belting the planet along the line between perpetual day and night, and that where the sunbeams touched these icy deposits near the edge of the light hemisphere a marvelous spectacle of prismatic hills of crystal would be presented!

It may be remarked that it would be the inhabitants of the dark hemisphere who would enjoy the beautiful scene of the earth and the moon in opposition.

CHAPTER IV

MARS, A WORLD MORE ADVANCED THAN OURS

Mars is the fourth planet in the order of distance from the sun, and the outermost member of the terrestrial group. Its mean distance is 141,500,000 miles, variable, through the eccentricity of its orbit, to the extent of about 13,000,000 miles. It will be observed that this is only a million miles less than the variation in Mercury's distance from the sun, from which, in a previous chapter, were deduced most momentous consequences; but, in the case of Mars, the ratio of the variation to the mean distance is far smaller than with Mercury, so that the effect upon the temperature of the planet is relatively insignificant.

Mars gets a little less than half as much solar light and heat as the earth receives, its situation in this respect being just the opposite to that of Venus. Its period of orbital revolution, or the length of its year, is 687 of our days. The diameter of Mars is 4,200 miles, and its density is 73 per cent of the earth's density. Gravity on its surface is only 38 per cent of terrestrial gravity—i.e., a one hundred-pound weight removed from the earth to Mars would there weigh but thirty-eight pounds. Mars evidently has an atmosphere, the details of which we shall discuss later.

The poles of the planet are inclined from a perpendicular to the plane of its orbit at very nearly the same angle as that of the earth's poles, viz., 24° 50′. Its rotation on its axis is also effected in almost the same period as the earth's, viz., 24 hours, 37 minutes.

When in opposition to the sun, Mars may be only about 35,000,000 miles from the earth, but its average distance when in that position is more than 48,000,000 miles, and may be more than 60,000,000. These differences arise from the eccentricities of the orbits of the two planets. When on the farther side of the sun—i.e., in conjunction with the sun as seen from the earth—Mars's average distance from us is about 235,000,000 miles. In consequence of these great changes in its distance, Mars is sometimes a very conspicuous object in the sky, and at other times inconspicuous.

The similarity in the inclination of the axis of the two planets results in a close resemblance between the seasons on Mars and on the earth, although, owing to the greater length of its year, Mars's seasons are much longer than ours. Winter and summer visit in succession its northern and southern hemispheres just as occurs on the planet that we inhabit, and the torrid, temperate, and frigid zones on its surface have nearly the same angular width as on the earth. In this respect Mars is the first of the foreign planets we have studied to resemble the earth.

Around each of its poles appears a circular white patch, which visibly expands when winter prevails upon it, and rapidly contracts, sometimes almost completely disappearing, under a summer sun. From the time of Sir William Herschel the almost universal belief among astronomers has been that these gleaming polar patches on Mars are composed of snow and ice, like the similar glacial caps of the earth, and no one can look at them with a telescope and not feel the liveliest interest in the planet to which they belong, for they impart to it an appearance of likeness to our globe which at first glance is all but irresistible.

To watch one of them apparently melting, becoming perceptibly smaller week after week, while the general surface of the corresponding hemisphere of the planet deepens in color, and displays a constantly increasing wealth of details as summer advances across it, is an experience of the most memorable kind, whose effect upon the mind of the observer is indescribable.

Early in the history of the telescope it became known that, in addition to the polar caps, Mars presented a number of distinct surface features, and gradually, as instruments increased in power and observers in skill, charts of the planet were produced showing a surface diversified somewhat in the manner that characterizes the face of the earth, although the permanent forms do not closely resemble those of our planet.

Two principal colors exist on the disk of Mars—dark, bluish gray or greenish gray, characterizing areas which have generally been regarded as seas, and light yellowish red, overspreading broad regions looked upon as continents. It was early observed that if the dark regions really are seas, the proportion of water to land upon Mars is much smaller than upon the earth.

For two especial reasons Mars has generally been regarded as an older or more advanced planet than the earth. The first reason is that, accepting Laplace's theory of the origin of the planetary system from a series of rings left off at the periphery of the contracting solar nebula, Mars must have come into existence earlier than the earth, because, being more distant from the center of the system, the ring from which it was formed would have been separated sooner than the terrestrial ring. The second reason is that Mars being smaller and less massive than the earth has run through its developments a cooling globe more rapidly. The bearing of these things upon the problems of life on Mars will be considered hereafter.

And now, once more, Schiaparelli appears as the discoverer of surprising facts about one of the most interesting worlds of the solar system. During the exceptionally favorable opposition of Mars in 1877, when an American astronomer, Asaph Hall, discovered the planet's two minute satellites, and again during the opposition of 1879, the Italian observer caught sight of an astonishing network of narrow dark lines intersecting the so-called continental regions of the planet and crossing one another in every direction. Schiaparelli did not see the little moons that Hall discovered, and Hall did not perceive the enigmatical lines that Schiaparelli detected. Hall had by far the larger and more powerful telescope; Schiaparelli had much the more steady and favorable atmosphere for astronomical observation. Yet these differences in equipment and circumstances do not clearly explain why each observer should have seen what the other did not.

There may be a partial explanation in the fact that an observer having made a remarkable discovery is naturally inclined to confine his attention to it, to the neglect of other things. But it was soon found that Schiaparelli's lines—to which he gave the name "canals," merely on account of their shape and appearance, and without any intention to define their real nature—were excessively difficult telescopic objects. Eight or nine years elapsed before any other observer corroborated Schiaparelli's observations, and notwithstanding the "sensation" which the discovery of the canals produced they were for many years regarded by the majority of astronomers as an illusion.

But they were no illusion, and in 1881 Schiaparelli added to the astonishment created by his original discovery, and furnished additional grounds for skepticism, by announcing that, at certain times, many of the canals geminated, or became double! He continued his observations at each subsequent opposition, adding to the number of the canals observed, and charting them with classical names upon a detailed map of the planet's surface.

At length in 1886 Perrotin, at Nice, detected many of Schiaparelli's canals, and later they were seen by others. In 1888 Schiaparelli greatly extended his observations, and in 1892 and 1894 some of the canals were studied with the 36-inch telescope of the Lick Observatory, and in the last-named year a very elaborate series of observations upon them was made by Percival Lowell and his associates, Prof. William C. Pickering and Mr. A.E. Douglass, at Flagstaff, Arizona. Mr. Lowell's charts of the planet are the most complete yet produced, containing 184 canals to which separate names have been given, besides more than a hundred other markings also designated by individual appellations.

It should not be inferred from the fact that Schiaparelli's discovery in 1877 excited so much surprise and incredulity that no glimpse of the peculiar canal-like markings on Mars had been obtained earlier than that. At least as long ago as 1864 Mr. Dawes, in England, had seen and sketched half a dozen of the larger canals, or at least the broader parts of them, especially where they connect with the dark regions known as seas, but Dawes did not see them in their full extent, did not recognize their peculiar character, and entirely failed to catch sight of the narrower and more numerous ones which constitute the wonderful network discovered by the Italian astronomer. Schiaparelli found no less than sixty canals during his first series of observations in 1877.

Let us note some of the more striking facts about the canals which Schiaparelli has described. We can not do better than quote his own words:

"There are on this planet, traversing the continents, long dark lines which may be designated as *canals*, although we do not yet know what they are. These lines run from one to another of the somber spots that are regarded as seas, and form, over the lighter, or continental, regions a well-defined network. Their arrangement appears to be invariable and permanent; at least, as far as I can judge from four and a half years of observation. Nevertheless, their aspect and their degree of visibility are not always the same, and depend upon circumstances which the present state of our knowledge does not yet permit us to explain with certainty. In 1879 a great number were seen which were not visible in 1877, and in 1882 all those which had been seen at former oppositions were found again, together with new ones. Sometimes these canals present themselves in the form of shadowy and vague lines, while on other occasions they are clear and precise, like a trace drawn with a pen. In general they are traced upon the sphere like the lines of great circles; a few show a sensible lateral curvature. They cross one another obliquely, or at right angles. They have a breadth of two degrees, or 120 kilometres [74 miles], and several extend over a length of eighty degrees, or 4,800 kilometres [nearly 3,000 miles]. Their tint is very nearly the same as that of the seas, usually a little lighter. Every canal terminates at both its extremities in a sea, or in another canal; there is not a single example of one coming to an end in the midst of dry land.

"This is not all. In certain seasons these canals become double. This phenomenon seems to appear at a determinate epoch, and to be produced simultaneously over the entire surface of the planet's continents. There was no indication of it in 1877, during the weeks that preceded and followed the summer solstice of that world. A single isolated case presented itself in 1879. On the 26th of December, this year—a little before the spring equinox, which occurred on Mars on the 21st of January, 1880—I noticed the doubling of the Nile [a canal thus named] between the Lakes of the Moon and the Ceraunic Gulf. These two regular, equal, and parallel lines caused me, I confess, a profound surprise, the more so because a few days earlier, on the 23d and the 24th of December, I had carefully observed that very region without discovering anything of the kind.

"I awaited with curiosity the return of the planet in 1881, to see if an analogous phenomenon would present itself in the same place, and I saw the same thing reappear on the 11th of January, 1882, one month after the spring equinox—which occurred on the 8th of December, 1881. The duplication was still more evident at the end of February. On this same date, the 11th of January, another duplication had already taken place, that of the middle portion of the canal of the Cyclops, adjoining Elysium. [Elysium is a part of one of the continental areas.]

"Yet greater was my astonishment when, on the 19th of January, I saw the canal Jamuna, which was then in the center of the disk, formed very rigidly of two parallel straight lines, crossing the space which separates the Niliac Lake from the Gulf of Aurora. At first sight I believed it was an illusion, caused by fatigue of the eye and some new kind of strabismus, but I had to yield to the evidence. After the 19th of January I simply passed from wonder to wonder; successively the Orontes, the Euphrates, the Phison, the Ganges, and the larger part of the other canals, displayed themselves very clearly and indisputably duplicated. There were not less than twenty examples of duplication, of which seventeen were observed in the space of a month, from the 19th of January to the 19th of February.

"In certain cases it was possible to observe precursory symptoms which are not lacking in interest. Thus, on the 13th of January, a light, ill-defined shade extended alongside the Ganges; on the 18th and the 19th one could only distinguish a series of white spots; on the 20th the shadow was still indecisive, but on the 21st the duplication was perfectly clear, such as I observed it until the 23d of February. The duplication of the Euphrates, of the canal of the Titans, and of the Pyriphlegethon also began in an uncertain and nebulous form.

"These duplications are not an optical effect depending on increase of visual power, as happens in the observation of double stars, and it is not the canal itself splitting in two longitudinally. Here is what is seen: To the right or left of a pre-existing line, without any change in the course and position of that line, one sees another line produce itself, equal and parallel to the first, at a distance generally varying from six to twelve degrees—i.e., from 350 to 700 kilometres (217 to 434 miles); even closer ones seem to be produced, but the telescope is not powerful enough to distinguish them with certainty. Their tint appears to be a quite deep reddish brown. The parallelism is sometimes rigorously exact. There is nothing analogous in terrestrial geography. Everything indicates that here there is an organization special to the planet Mars, probably connected with the course of its seasons."[1]

Schiaparelli adds that he took every precaution to avoid the least suspicion of illusion. "I am absolutely sure," he says, "of what I have observed."

I have quoted his statement, especially about the duplication of the canals, at so much length, both on account of its intrinsic interest and because it has many times been argued that this particular phenomenon must be illusory even though the canals are real.

One of the most significant facts that came out in the early observations was the evident connection between the appearance of the canals and the seasonal changes on Mars. It was about the time of the spring equinox, when the white polar caps had begun to melt, that Schiaparelli first noticed the phenomenon of duplication. As the season advanced the doubling of the canals increased in frequency and the lines became more distinct. In the meantime the polar caps were becoming smaller. Broadly speaking, Schiaparelli's observation showed that the doubling of the canals occurred principally a little after the spring equinox and a little before the autumn equinox; that the phenomenon disappeared in large part at the epoch of the winter solstice, and disappeared altogether at the epoch of the summer solstice. Moreover, he observed that many of the canals, without regard to duplication, were invisible at times, and reappeared gradually; faint, scarcely visible lines and shadows, deepened and became more distinct until they were clearly and sharply defined, and these changes, likewise, were evidently seasonal.

The invariable connection of the canals at their terminations with the regions called seas, the fact that as the polar caps disappeared the sealike expanses surrounding the polar regions deepened in color, and other similar considerations soon led to the suggestion that there existed on Mars a wonderful system of water circulation, whereby the melting of the polar snows, as summer passed alternately from one hemisphere to the other, served to reenforce the supply of water in the seas, and, through the seas, in the canals traversing the broad expanses of dry land that occupy the equatorial regions of the planet. The thought naturally occurred that the canals might be of artificial origin, and might indicate the existence of a gigantic system of irrigation serving to maintain life upon the globe of Mars. The geometrical perfection of the lines, their straightness, their absolute parallelism when doubled, their remarkable tendency to radiate from definite centers, lent strength to the hypothesis of an artificial origin. But their enormous size, length, and number tended to stagger belief in the ability of the inhabitants of any world to achieve a work so stupendous.

After a time a change of view occurred concerning the nature of the expanses called seas, and Mr. Lowell, following his observations of 1894, developed the theory of the water circulation and irrigation of Mars in a new form. He and others observed that occasionally canals were visible cutting straight across some of the greenish, or bluish-gray, areas that had been regarded as seas. This fact suggested that, instead of seas, these dark expanses may rather be areas of marshy ground covered with vegetation which flourishes and dies away according as the supply of water alternately increases and diminishes, while the reddish areas known as continents are barren deserts, intersected by canals; and as the water released by the melting of the polar snows begins to fill the canals, vegetation springs up along their sides and becomes visible in the form of long narrow bands.

According to this theory, the phenomena called canals are simply lines of vegetation, the real canals being individually too small to be detected. It may be supposed that from a central supply canal irrigation ditches are extended for a distance of twenty or thirty miles on each side, thus producing a strip of fertile soil from forty to sixty miles wide, and hundreds, or in some cases two or three thousands, of miles in length.

The water supply being limited, the inhabitants can not undertake to irrigate the entire surface of the thirsty land, and convenience of circulation induces them to extend the irrigated areas in the form of long lines. The surface of Mars, according to Lowell's observation, is remarkably flat and level, so that no serious obstacle exists to the extension of the canal system in straight bands as undeviating as arcs of great circles.

Wherever two or more canals meet, or cross, a rounded dark spot from a hundred miles, or less, to three hundred miles in diameter, is seen. An astonishing number of these appear on Mr. Lowell's charts. Occasionally, as occurs at the singular spot named Lacus Solis, several canals converging from all points of the compass meet at a central point like the spokes of a wheel; in other cases, as, for instance, that of the long canal named Eumenides, with its continuation Orcus, a single conspicuous line is seen threading a large number of round dark spots, which present the appearance of a row of beads upon a string. These circular spots, which some have regarded as lakes, Mr. Lowell believes are rather oases in the great deserts, and granting the correctness of his theory of the canals the aptness of this designation is apparent.[2]

Wherever several canals, that is to say, several bands of vegetation or bands of life, meet, it is reasonable to assume that an irrigated and habitable area of considerable extent will be developed, and in such places the imagination may picture the location of the chief centers of population, perhaps in the form of large cities, or perhaps in groups of smaller towns and villages. The so-called Lacus Solis is one of these localities.

So, likewise, it seems but natural that along the course of a broad, well-irrigated band a number of expansions should occur, driving back the bounds of the desert, forming rounded areas of vegetation, and thus affording a footing for population. Wherever two bands cross such areas would be sure to exist, and in almost every instance of crossing the telescope actually shows them.

As to the gemination or duplication of many of the lines which, at the beginning of the season, appear single, it may be suggested that, in the course of the development of the vast irrigation system of the planet parallel bands of cultivation have been established, one receiving its water supply from the canals of the other, and consequently lagging a little behind in visibility as the water slowly percolates through the soil and awakens the vegetation. Or else, the character of the vegetation itself may differ as between two such parallel bands, one being supplied with plants that spring up and mature quickly when the soil about their roots is moistened, while the plants in the twin band respond more slowly to stimulation.

Objection has been made to the theory of the artificial origin of the canals of Mars on the ground, already mentioned, that the work required to construct them would be beyond the capacity of any race of creatures resembling man. The reply that has been made to this is twofold. In the first place, it should be remembered that the theory, as Mr. Lowell presents it, does not assert that the visible lines are the actual canals, but only that they are strips of territory intersected, like Holland or the center of the plain of Lombardy, by innumerable irrigation canals and ditches. To construct such works is clearly not an impossible undertaking, although it does imply great industry and concentration of effort.

In the second place, since the force of gravity on Mars is in the ratio of only 38 to 100 compared with the earth's, it is evident that the diminished weight of all bodies to be handled would give the inhabitants of Mars an advantage over those of the earth in the performance of manual labor, provided that they possess physical strength and activity as great as ours. But, in consequence of this very fact of the slighter force of gravity, a man upon Mars could attain a much greater size, and consequently much greater muscular strength, than his fellows upon the earth possess without being oppressed by his own weight. In other words, as far as the force of gravity may be considered as the decisive factor, Mars could be inhabited by giants fifteen feet tall, who would be relatively just as active, and just as little impeded in their movements by the weight of their bodies, as a six-footer is upon the earth. But they would possess far more physical strength than we do, while, in doing work, they would have much lighter materials to deal with.

Whether the theory that the canals of Mars really are canals is true or not, at any rate there can now be no doubt as to the existence of the strange lines which bear that designation. The suggestion has been offered that their builders may no longer be in existence, Mars having already passed the point in its history where life must cease upon its surface. This brings us to consider again the statement, made near the beginning of this chapter, that Mars is, perhaps, at a more advanced stage of development than the earth. If we accept this view, then, provided there was originally some resemblance between Mars's life forms and those of the earth, the inhabitants of that planet would, at every step, probably be in front of their terrestrial rivals, so that at the present time they should stand well in advance. Mr. Lowell has, perhaps, put this view of the relative advancement in evolution of Mars and its inhabitants as picturesquely as anybody.

"In Mars," he says, "we have before us the spectacle of a world relatively well on in years, a world much older than the earth. To so much about his age Mars bears witness on his face. He shows unmistakable signs of being old. Advancing planetary years have left their mark legible there. His continents are all smoothed down; his oceans have all dried up…. Mars being thus old himself, we know that evolution on his surface must be similarly advanced. This only informs us of its condition relative to the planet's capabilities. Of its actual state our data are not definite enough to furnish much deduction. But from the fact that our own development has been comparatively a recent thing, and that a long time would be needed to bring even Mars to his present geological condition, we may judge any life he may support to be not only relatively, but really older than our own. From the little we can see such appears to be the case. The evidence of handicraft, if such it be, points to a highly intelligent mind behind it. Irrigation, unscientifically conducted, would not give us such truly wonderful mathematical fitness in the several parts to the whole as we there behold…. Quite possibly such Martian folk are possessed of inventions of which we have not dreamed, and with them electrophones and kinetoscopes are things of a bygone past, preserved with veneration in museums as relics of the clumsy contrivances of the simple childhood of the race. Certainly what we see hints at the existence of beings who are in advance of, not behind us, in the journey of life."[3]

Granted the existence of such a race as is thus described, and to them it might not seem a too appalling enterprise, when their planet had become decrepit, with its atmosphere thinned out and its supply of water depleted, to grapple with the destroying hand of nature and to prolong the career of their world by feats of chemistry and engineering as yet beyond the compass of human knowledge.

It is confidence, bred from considerations like these, in the superhuman powers of the supposed inhabitants of Mars that has led to the popular idea that they are trying to communicate by signals with the earth. Certain enigmatical spots of light, seen at the edge of the illuminated disk of Mars, and projecting into the unilluminated part—for Mars, although an outer planet, shows at particular times a gibbous phase resembling that of the moon just before or just after the period of full moon—have been interpreted by some, but without any scientific evidence, as of artificial origin.

Upon the assumption that these bright points, and others occasionally seen elsewhere on the planet's disk, are intended by the Martians for signals to the earth, entertaining calculations have been made as to the quantity of light that would be required in the form of a "flash signal" to be visible across the distance separating the two planets. The results of the calculations have hardly been encouraging to possible investors in interplanetary telegraphy, since it appears that heliographic mirrors with reflecting surfaces measured by square miles, instead of square inches, would be required to send a visible beam from the earth to Mars or *vice versa*.

The projections of light on Mars can be explained much more simply and reasonably. Various suggestions have been made about them; among others, that they are masses of cloud reflecting the sunshine; that they are areas of snow; and that they are the summits of mountains crowned with ice and encircled with clouds. In fact, a huge mountain mass lying on the terminator, or the line between day and night, would produce the effect of a tongue of light projecting into the darkness without assuming that it was snow-covered or capped with clouds, as any one may convince himself by studying the moon with a telescope when the terminator lies across some of its most mountainous regions. To be sure, there is reason to think that the surface of Mars is remarkably flat; yet even so the planet may have some mountains, and on a globe the greater part of whose shell is smooth any projections would be conspicuous, particularly where the sunlight fell at a low angle across them.

Another form in which the suggestion of interplanetary communication has been urged is plainly an outgrowth of the invention and surprising developments of wireless telegraphy. The human mind is so constituted that whenever it obtains any new glimpse into the arcana of nature it immediately imagines an indefinite and all but unlimited extension of its view in that direction. So to many it has not appeared unreasonable to assume that, since it is possible to transmit electric impulses for considerable distances over the earth's surface by the simple propagation of a series of waves, or undulations, without connecting wires, it may also be possible to send such impulses through the ether from planet to planet.

The fact that the electric undulations employed in wireless telegraphy pass between stations connected by the crust of the earth itself, and immersed in a common atmospheric envelope, is not deemed by the supporters of the theory in question as a very serious objection, for, they contend, electric waves are a phenomenon of the ether, which extends throughout space, and, given sufficient energy, such waves could cross the gap between world and world.

But nobody has shown how much energy would be needed for such a purpose, and much less has anybody indicated a way in which the required energy could be artificially developed, or cunningly filched from the stores of nature. It is, then, purely an assumption, an interesting figment of the mind, that certain curious disturbances in the electrical state of the air and the earth, affecting delicate electric instruments, possessing a marked periodicity in brief intervals of time, and not yet otherwise accounted for, are due to the throbbing, in the all-enveloping ether, of impulses transmitted from instruments controlled by the *savants* of Mars, whose insatiable thirst for knowledge, and presumably burning desire to learn whether there is not within reach some more fortunate world than their half-dried-up globe, has led them into a desperate attempt to "call up" the earth on their interplanetary telephone, with the hope that we are wise and skilful enough to understand and answer them.

In what language they intend to converse no one has yet undertaken to tell, but the suggestion has sapiently been made that, mathematical facts being invariable, the eternal equality of two plus two with four might serve as a basis of understanding, and that a statement of that truth sent by electric taps across the ocean of ether would be a convincing assurance that the inhabitants of the planet from which the message came at least enjoyed the advantages of a common-school education.

But, while speculation upon this subject rests on unverified, and at present unverifiable, assumptions, of course everybody would rejoice if such a thing were possible, for consider what zest and charm would be added to human life if messages, even of the simplest description, could be sent to and received from intelligent beings inhabiting other planets! It is because of this hold that it possesses upon the imagination, and the pleasing pictures that it conjures up, that the idea of interplanetary communication, once broached, has become so popular a topic, even though everybody sees that it should not be taken too seriously.

The subject of the atmosphere of Mars can not be dismissed without further consideration than we have yet given it, because those who think the planet uninhabitable base their opinion largely upon the assumed absence of sufficient air to support life. It was long ago recognized that, other things being equal, a planet of small mass must possess a less dense atmosphere than one of large mass. Assuming that each planet originally drew from a common stock, and that the amount and density of its atmosphere is measured by its force of gravity, it can be shown that Mars should have an atmosphere less than one fifth as dense as the earth's.

Dr. Johnstone Stoney has attacked the problem of planetary atmospheres in another way. Knowing the force of gravity on a planet, it is easy to calculate the velocity with which a body, or a particle, would have to start radially from the planet in order to escape from its gravitational control. For the earth this critical velocity is about seven miles per second; for Mars about three miles per second. Estimating the velocity of the molecules of the various atmospheric gases, according to the kinetic theory, Dr. Stoney finds that some of the smaller planets, and the moon, are gravitationally incapable of retaining all of these gases in the form of an atmosphere. Among the atmospheric constituents that, according to this view, Mars would be unable permanently to retain is water vapor. Indeed, he supposes that even the earth is slowly losing its water by evaporation into space, and on Mars, owing to the slight force of gravity there, this process would go on much more rapidly, so that, in this way, we have a means of accounting for the apparent drying up of that planet, while we may be led to anticipate that at some time in the remote future the earth also will begin to suffer from lack of water, and that eventually the chasms of the sea will yawn empty and desolate under a cloudless sky.

But it is not certain that the original supply of atmospheric elements was in every case proportional to the respective force of gravity of a planet. The fact that Venus appears to have an atmosphere more extensive and denser than the earth's, although its force of gravity is a little less than that of our globe, indicates at once a variation as between these two planets in the amount of atmospheric material at their disposal. This may be a detail depending upon differences in the mode, or in the stage, of their evolution. Thus, after all, Dr. Stoney's theory may be substantially correct and yet Mars may retain sufficient water to form clouds, to be precipitated in snow, and to fill its canals after each annual melting of the polar caps, because the original supply was abundant, and its escape is a gradual process, only to be completed by age-long steps.

Even though the evidence of the spectroscope, as far as it goes, seems to lend support to the theory that there is no water vapor in the atmosphere of Mars, we can not disregard the visual evidence that, nevertheless, water vapor exists there.

What are the polar caps if they are not snow? Frozen carbon dioxide, it has been suggested; but this is hardly satisfactory, for it offers no explanation of the fact that when the polar caps diminish, and in proportion as they diminish, the "seas" and the canals darken and expand, whereas a reasonable explanation of the correlation of these phenomena is offered if we accept the view that the polar caps consist of snow.

Then there are many observations on record indicating the existence of clouds in Mars's atmosphere. Sometimes a considerable area of its surface has been observed to be temporarily obscured, not by dense masses of cloud such as accompany the progress of great cyclonic storms across the continents and oceans of the earth, but by comparatively thin veils of vapor such as would be expected to form in an atmosphere so comparatively rare as that of Mars. And these clouds, in some instances at least, appear, like the cirrus streaks and dapples in our own air, to float at a great elevation. Mr. Douglass, one of Mr. Lowell's associates in the observations of 1894 at Flagstaff, Arizona, observed what he believed to be a cloud over the unilluminated part of Mars's disk, which, by micrometric measurement and estimate, was drifting at an elevation of about fifteen miles above the surface of the planet. This was seen on two successive days, November 25th and November 26th, and it underwent curious fluctuations in visibility, besides moving in a northerly direction at the rate of some thirteen miles an hour. But, upon the whole, as Mr. Lowell remarks, the atmosphere of Mars is remarkably free of clouds.

The reader will remember that Mars gets a little less than half as much heat from the sun as the earth gets. This fact also has been used as an argument against the habitability of the planet. In truth, those who think that life in the solar system is confined to the earth alone insist upon an almost exact reproduction of terrestrial conditions as a *sine qua non* to the habitability of any other planet. Venus, they think, is too hot, and Mars too cold, as if life were rather a happy accident than the result of the operation of general laws applicable under a wide variety of conditions. All that we are really justified in asserting is that Venus may be too hot and Mars too cold for *us*. Of course, if we adopt the opinion held by some that the temperature on Mars is constantly so low that water would remain perpetually frozen, it does throw the question of the kind of life that could be maintained there into the realm of pure conjecture.

The argument in favor of an extremely low temperature on Mars is based on the law of the diminution of radiant energy inversely as the square of the distance, together with the assumption that no qualifying circumstances, or no modification of that law, can enter into the problem. According to this view, it could be shown that the temperature on Mars never rises above -200° F. But it is a view that seems to be directly opposed to the evidence of the telescope, for all who have studied Mars under favorable conditions of observation have been impressed by the rapid and extensive changes that the appearance of its surface undergoes coincidently with the variation of the planet's seasons. It has its winter aspect and its summer aspect, perfectly distinct and recognizable, in each hemisphere by turns, and whether the polar caps be snow or carbon dioxide, at any rate they melt and disappear under a high sun, thus proving that an accumulation of heat takes place.

Professor Young says: "As to the temperature of Mars we have no certain knowledge. On the one hand, we know that on account of the planet's distance from the sun the intensity of solar radiation upon its surface must be less than here in the ratio of 1 to $(1.524)^2$—i.e., only about 43 per cent as great as with us; its 'solar constant' must be less than 13 calories against our 30. Then, too, the low density of its atmosphere, probably less at the planet's surface than on the tops of our highest mountains, would naturally assist to keep down the temperature to a point far below the freezing-point of water. But, on the other hand, things certainly *look* as if the polar caps were really masses of *snow* and *ice* deposited from vapor in the planet's atmosphere, and as if these actually melted during the Martian summer, sending floods of water through the channels provided for them, and causing the growth of vegetation along their banks. We are driven, therefore, to suppose either that the planet has sources of heat internal or external which are not yet explained, or else, as long ago suggested, that the polar 'snow' may possibly be composed of something else than frozen *water*."[4]

Even while granting the worst that can be said for the low temperature of Mars, the persistent believer in its habitability could take refuge in the results of recent experiments which have proved that bacterial life is able to resist the utmost degree of cold that can be applied, microscopic organisms perfectly retaining their vitality—or at least their power to resume it—when subjected to the fearfully low temperature of liquid air. But then he would be open to the reply that the organisms thus treated are in a torpid condition and deprived of all activity until revived by the application of heat; and the picture of a world in a state of perpetual sleep is not particularly attractive, unless the fortunate prince who is destined to awake the slumbering beauty can also be introduced into the romance.[5]

To an extent which most of us, perhaps, do not fully appreciate, we are indebted for many of the pleasures and conveniences and some of the necessities of life on our planet to its faithful attendant, the moon. Neither Mercury nor Venus has a moon, but Mars has two moons. This statement, standing alone, might lead to the conclusion that, as far as the advantages a satellite can afford to the inhabitants of its master planet are concerned, the people of Mars are doubly fortunate. So they would be, perhaps, if Mars's moons were bodies comparable in size with our moon, but in fact they are hardly more than a pair of very entertaining astronomical toys. The larger of the two, Phobos, is believed to be about seven miles in diameter; the smaller, Deimos, only five or six miles. Their dimensions thus resemble those of the more minute of the asteroids, and the suggestion has even been made that they may be captured asteroids which have fallen under the gravitational control of Mars.

The diameters just mentioned are Professor Pickering's estimates, based on the amount of light the little satellites reflect, for they are much too small to present measurable disks. Deimos is 14,600 miles from the center of Mars and 12,500 miles from its surface. Phobos is 5,800 miles from the center of the planet and only 3,700 from the surface. Deimos completes a revolution about the planet in thirty hours and eighteen minutes, and Phobos in the astonishingly short period—although, of course, it is in strict accord with the law of gravitation and in that sense not astonishing—of seven hours and thirty-nine minutes.

Since Mars takes twenty-four hours and thirty-seven minutes for one rotation on its axis, it is evident that Phobos goes round the planet three times in the course of a single Martian day and night, rising, contrary to the general motion of the heavens, in the west, running in a few hours through all the phases that our moon exhibits in the course of a month, and setting, where the sun and all the stars rise, in the east. Deimos, on the other hand, has a period of revolution five or six hours longer than that of the planet's axial rotation, so that it rises, like the other heavenly bodies, in the east; but, because its motion is so nearly equal, in angular velocity, to that of Mars's rotation, it shifts very slowly through the sky toward the west, and for two or three successive days and nights it remains above the horizon, the sun overtaking and passing it again and again, while, in the meantime, its protean face swiftly changes from full circle to half-moon, from half-moon to crescent, from crescent back to half, and from half to full, and so on without ceasing.

And during this time Phobos is rushing through the sky in the opposite direction, as if in defiance of the fundamental law of celestial revolution, making a complete circuit three times every twenty-four hours, and changing the shape of its disk four times as rapidly as Deimos does! Truly, if we were suddenly transported to Mars, we might well believe that we had arrived in the mother world of lunatics, and that its two moons were bewitched. Yet it must not be supposed that all the peculiarities just mentioned would be clearly seen from the surface of Mars by eyes like ours. The phases of Phobos would probably be discernible to the naked eye, but those of Deimos would require a telescope in order to be seen, for, notwithstanding their nearness to the planet, Mars's moons are inconspicuous phenomena even to the Martians themselves. Professor Young's estimate is that Phobos may shed upon Mars one-sixtieth and Deimos one-twelve-hundredth as much reflected moonlight as our moon sends to the earth. Accordingly, a "moonlit night" on Mars can have no such charm as we associate with the phrase. But it is surely a tribute to the power and perfection of our telescopes that we have been able to discover the existence of objects so minute and inconspicuous, situated at a distance of many millions of miles, and half concealed by the glaring light of the planet close around which they revolve.

If Mars's moons were as massive as our moon is they would raise tremendous tides upon Mars, and would affect the circulation of water in the canals, but, in fact, their tidal effects are even more insignificant than their light-giving powers. But for astronomers on Mars they would be objects of absorbing interest.

Upon quitting Mars we pass to the second distinctive planetary group of the solar system, that of the asteroids.

CHAPTER V

THE ASTEROIDS, A FAMILY OF DWARF WORLDS

Beyond Mars, in the broad gap separating the terrestrial from the Jovian planets, are the asteroids, of which nearly five hundred have been discovered and designated by individual names or numbers. But any statement concerning the known number of asteroids can remain valid for but a short time, because new ones are continually found, especially by the aid of photography. Very few of the asteroids are of measurable size. Among these are the four that were the first to be discovered—Ceres, Pallas, Juno, and Vesta. Their diameters, according to the measurements of Prof. E.E. Barnard, of the Yerkes Observatory, are as follows: Ceres, 477 miles; Pallas, 304 miles; Juno, 120 miles; Vesta, 239 miles.

It is only necessary to mention these diameters in order to indicate how wide is the difference between the asteroids and such planets as the earth, Venus, or Mars. The entire surface of the largest asteroid, Ceres, does not equal the republic of Mexico in area. But Ceres itself is gigantic in comparison with the vast majority of the asteroids, many of which, it is believed, do not exceed twenty miles in diameter, while there may be hundreds or thousands of others still smaller—ten miles, five miles, or perhaps only a few rods, in diameter!

Curiously enough, the asteroid which appears brightest, and which it would naturally be inferred is the largest, really stands third in the order of measured size. This is Vesta, whose diameter, according to Barnard, is only 239 miles. It is estimated that the surface of Vesta possesses about four times greater light-reflecting power than the surface of Ceres. Some observations have also shown a variation in the intensity of the light from Vesta, a most interesting fact, which becomes still more significant when considered in connection with the great variability of another most extraordinary member of the asteroidal family, Eros, which is to be described presently.

The orbits of the asteroids are scattered over a zone about 200,000,000 miles broad. The mean distance from the sun of the nearest asteroid, Eros, is 135,000,000 miles, and that of the most distant, Thule, 400,000,000 miles. Wide gaps exist in the asteroidal zone where few or no members of the group are to be found, and Prof. Daniel Kirkwood long ago demonstrated the influence of Jupiter in producing these gaps. Almost no asteroids, as he showed, revolve at such a distance from the sun that their periods of revolution are exactly commensurable with that of Jupiter. Originally there may have been many thus situated, but the attraction of the great planet has, in the course of time, swept those zones clean.

Many of the asteroids have very eccentric orbits, and their orbits are curiously intermixed, varying widely among themselves, both in ellipticity and in inclination to the common plane of the solar system.

Considered with reference to the shape and position of its orbit, the most unique of these little worlds is Eros, which was discovered in 1898 by De Witt, at Berlin, and which, on account of its occasional near approach to the earth, has lately been utilized in a fresh attempt to obtain a closer approximation to the true distance of the sun from the earth. The mean distance of Eros from the sun is 135,000,000 miles, its greatest distance is

166,000,000 miles, and its least distance 105,000,000 miles. It will thus be seen that, although all the other asteroids are situated beyond Mars, Eros, at its mean distance, is nearer to the sun than Mars is. When in aphelion, or at its greatest distance, Eros is outside of the orbit of Mars, but when in perihelion it is so much inside of Mars's orbit that it comes surprisingly near the earth.

Indeed, there are times when Eros is nearer to the earth than any other celestial body ever gets except the moon—and, it might be added, except meteors and, by chance, a comet, or a comet's tail. Its least possible distance from the earth is less than 14,000,000 miles, and it was nearly as close as that, without anybody knowing or suspecting the fact, in 1894, four years in advance of its discovery. Yet the fact, strange as the statement may seem, had been recorded without being recognized. After De Witt's discovery of Eros in 1898, at a time when it was by no means as near the earth as it had been some years before, Prof. E.C. Pickering ascertained that it had several times imprinted its image on the photographic plates of the Harvard Observatory, with which pictures of the sky are systematically taken, but had remained unnoticed, or had been taken for an ordinary star among the thousands of star images surrounding it. From these telltale plates it was ascertained that in 1894 it had been in perihelion very near the earth, and had shone with the brilliance of a seventh-magnitude star.

It will, unfortunately, be a long time before Eros comes quite as near us as it did on that occasion, when we failed to see it, for its close approaches to the earth are not frequent. Prof. Solon I. Bailey selects the oppositions of Eros in 1931 and 1938 as probably the most favorable that will occur during the first half of the twentieth century.

We turn to the extraordinary fluctuations in the light of Eros, and the equally extraordinary conclusions drawn from them. While the little asteroid, whose diameter is estimated to be in the neighborhood of twenty or twenty-five miles, was being assiduously watched and photographed during its opposition in the winter of 1900-1901, several observers discovered that its light was variable to the extent of more than a whole magnitude; some said as much as two magnitudes. When it is remembered that an increase of one stellar magnitude means an accession of light in the ratio of 2.5 to 1, and an increase of two magnitudes an accession of 6.25 to 1, the significance of such variations as Eros exhibited becomes immediately apparent. The shortness of the period within which the cycle of changes occurred, about two hours and a half, made the variation more noticeable, and at the same time suggested a ready explanation, viz., that the asteroid was rapidly turning on its axis, a thing, in itself, quite in accordance with the behavior of other celestial bodies and naturally to be expected.

But careful observation showed that there were marked irregularities in the light fluctuations, indicating that Eros either had a very strange distribution of light and dark areas covering its surface, or that instead of being a globular body it was of some extremely irregular shape, so that as it rotated it presented successively larger and smaller reflecting surfaces toward the sun and the earth. One interesting suggestion was that the little planet is in reality double, the two components revolving around their common center of gravity, like a close binary star, and mutually eclipsing one another. But this theory seems hardly competent to explain the very great fluctuation in light, and a better one, probably, is that suggested by Prof. E.C. Pickering, that Eros is shaped something like a dumb-bell.

We can picture such a mass, in imagination, tumbling end over end in its orbit so as to present at one moment the broad sides of both bells, together with their connecting neck, toward the sun, and, at the same time, toward the observer on the earth, and, at another moment, only the end of one of the bells, the other bell and the neck being concealed in shadow. In this way the successive gain and loss of sixfold in the amount of light might be accounted for. Owing to the great distance the real form of the asteroid is imperceptible even with powerful telescopes, but the effect of a change in the amount of reflecting surface presented produces, necessarily, an alternate waxing and waning of the light. As far as the fluctuations are concerned, they might also be explained by supposing that the shape of the asteroid is that of a flat disk, rotating about one of its larger diameters so as to present, alternately, its edge and its broadside to the sun. And, perhaps, in order completely to account for all the observed eccentricities of the light of Eros, the irregularity of form may have to be supplemented by certain assumptions as to the varying reflective capacity of different parts of the misshapen mass.

The invaluable Harvard photographs show that long before Eros was recognized as an asteroid its light variations had been automatically registered on the plates. Some of the plates, Prof. E.C. Pickering says, had had an exposure of an hour or more, and, owing to its motion, Eros had formed a trail on each of these plates, which in some cases showed distinct variations in brightness. Differences in the amount of variation at different times will largely depend upon the position of the earth with respect to the axis of rotation.

Another interesting deduction may be made from the changes that the light of Eros undergoes. We have already remarked that one of the larger asteroids, and the one which appears to the eye as the most brilliant of all, Vesta, has been suspected of variability, but not so extensive as that of Eros. Olbers, at the beginning of the last century, was of the opinion that Vesta’s variations were due to its being not a globe but an angular mass. So he was led by a similar phenomenon to precisely the same opinion about Vesta that has lately been put forth concerning Eros. The importance of this coincidence is that it tends to revive a remarkable theory of the origin of the asteroids which has long been in abeyance, and, in the minds of many, perhaps discredited.

This theory, which is due to Olbers, begins with the startling assumption that a planet, perhaps as large as Mars, formerly revolving in an orbit situated between the orbits of Mars and Jupiter, was destroyed by an explosion! Although, at first glance, such a catastrophe may appear too wildly improbable for belief, yet it was not the improbability of a world’s blowing up that led to a temporary abandonment of Olbers’s bold theory. The great French mathematician Lagrange investigated the explosive force “which would be necessary to detach a fragment of matter from a planet revolving at a given distance from the sun,” and published the results in the Connaissance des Temps for 1814.

“Applying his results to the earth, Lagrange found that if the velocity of the detached fragment exceeded that of a cannon ball in the proportion of 121 to 1 the fragment would become a comet with a direct motion; but if the velocity rose in the proportion of 156 to 1 the motion of the comet would be retrograde. If the velocity was less than in either of these cases the fragment would revolve as a planet in an elliptic orbit. For any other planet besides the earth the velocity of explosion corresponding to the different cases would vary in the inverse ratio of the square root of the mean distance. It would therefore manifestly be less as the planet was more distant from the sun. In the case of each of the four smaller planets (only the four asteroids, Ceres, Pallas, Juno, and Vesta, were known at that time), the velocity of explosion indicated by their observed motion would be less than twenty times the velocity of a cannon ball."[6]

Instead, then, of being discredited by its assumption of so strange a catastrophe, Olbers's theory fell into desuetude because of its apparent failure to account for the position of the orbits of many of the asteroids after a large number of those bodies had been discovered. He calculated that the orbits of all the fragments of his exploded planet would have nearly equal mean distances, and a common point of intersection in the heavens, through which every fragment of the original mass would necessarily pass in each revolution. At first the orbits of the asteroids discovered seemed to answer to these conditions, and Olbers was even able to use his theory as a means of predicting the position of yet undetected asteroids. Only Ceres and Pallas had been discovered when he put forth his theory, but when Juno and Vesta were found they fell in with his predictions so well that the theory was generally regarded as being virtually established; while the fluctuations in the light of Vesta, as we have before remarked, led Olbers to assert that that body was of a fragmental shape, thus strongly supporting his explosion hypothesis.

Afterward, when the orbits of many asteroids had been investigated, the soundness of Olbers's theory began to be questioned. The fact that the orbits did not all intersect at a common point could easily be disposed of, as Professor Newcomb has pointed out, by simply placing the date of the explosion sufficiently far back, say millions of years ago, for the secular changes produced by the attraction of the larger planets would effectively mix up the orbits. But when the actual effects of these secular changes were calculated for particular asteroids the result seemed to show that "the orbits could never have intersected unless some of them have in the meantime been altered by the attraction of the small planets on each other. Such an action is not impossible, but it is impossible to determine it, owing to the great number of these bodies and our ignorance of their masses."[7]

Yet the theory has never been entirely thrown out, and now that the discovery of the light fluctuations of Eros lends support to Olbers's assertion of the irregular shape of some of the asteroids, it is very interesting to recall what so high an authority as Professor Young said on the subject before the discovery of Eros:

"It is true, as has often been urged, that this theory in its original form, as presented by Olbers, can not be correct. No *single* explosion of a planet could give rise to the present assemblage of orbits, nor is it possible that even the perturbations of Jupiter could have converted a set of orbits originally all crossing at one point (the point of explosion) into the present tangle. The smaller orbits are so small that, however turned about, they lie wholly inside the larger and can not be made to intersect them. If, however, we admit a *series* of explosions, this difficulty is removed; and if we grant an explosion at all, there seems to be nothing improbable in the hypothesis that the fragments formed by the bursting of the parent mass would carry away within themselves the same forces and reactions which caused the original bursting, so that they themselves would be likely enough to explode at some time in their later history."[8]

The rival theory of the origin of the asteroids is that which assumes that the planetary ring originally left off from the contracting solar nebula between the orbits of Mars and Jupiter was so violently perturbed by the attraction of the latter planet that, instead of being shaped into a single globe, it was broken up into many fragments. Either hypothesis presents an attractive picture; but that which presupposes the bursting asunder of a large planet, which might at least have borne the germs of life, and the subsequent shattering of its parts into smaller fragments, like the secondary explosions of the pieces of a pyrotechnic bomb, certainly is by far the more impressive in its appeal to the imagination, and would seem to offer excellent material for some of the extra-terrestrial romances now so popular. It is a startling thought that a world can possibly carry within itself, like a dynamite cartridge, the means of its own disruption; but the idea does not appear so extremely improbable when we recall the evidence of collisions or explosions, happening on a tremendous scale, in the case of new or temporary stars.[9]

Coming to the question of life upon the asteroids, it seems clear that they must be excluded from the list of habitable worlds, whatever we may choose to think of the possible habitability of the original planet through whose destruction they may have come into existence. The largest of them possesses a force of gravity far too slight to enable it to retain any of the gases or vapors that are recognized as constituting an atmosphere. But they afford a captivating field for speculation, which need not be altogether avoided, for it offers some graphic illustrations of the law of gravitation. A few years ago I wrote, for the entertainment of an audience which preferred to meet science attired in a garb woven largely from the strands of fancy, an account of some of the peculiarities of such minute globes as the asteroids, which I reproduce here because it gives, perhaps, a livelier picture of those little bodies, from the point of view of ordinary human interest, than could be presented in any other way.

A WAIF OF SPACE

One night as I was waiting, watch in hand, for an occultation, and striving hard to keep awake, for it had been a hot and exhausting summer's day, while my wife—we were then in our honeymoon—sat sympathetically by my side, I suddenly found myself withdrawn from the telescope, and standing in a place that appeared entirely strange. It was a very smooth bit of ground, and, to my surprise, there was no horizon in sight; that is to say, the surface of the ground disappeared on all sides at a short distance off, and beyond nothing but sky was visible. I thought I must be on the top of a stupendous mountain, and yet I was puzzled to understand how the face of the earth could be so far withdrawn. Presently I became aware that there was some one by me whom I could not see.

"You are not on a mountain," my companion said, and as he spoke a cold shiver ran along my back-bone; "you are on an asteroid, one of those miniature planets, as you astronomers call them, and of which you have discovered several hundred revolving between the orbits of Mars and Jupiter. This is the little globe that you have glimpsed occasionally with your telescope, and that you, or some of your fellows, have been kind enough to name Menippe."

Then I perceived that my companion, whose address had hardly been reassuring, was a gigantic inhabitant of the little planet, towering up to a height of three quarters of a mile. For a moment I was highly amused, standing by his foot, which swelled up like a hill, and straining my neck backward to get a look up along the precipice of his leg, which, curiously enough, I observed was clothed in rough homespun, the woolly knots of the cloth appearing of tremendous size, while it bagged at the knee like any terrestrial trousers' leg. His great head and face I could see far above me, as it were, in the clouds. Yet I was not at all astonished.

"This is all right," I said to myself. "Of course on Menippe the people must be as large as this, for the little planet is only a dozen miles in diameter, and the force of gravity is consequently so small that a man without loss of activity, or inconvenience, can grow three quarters of a mile tall."

Suddenly an idea occurred to me. "Just to think what a jump I can make! Why, only the other day I was figuring it out that a man could easily jump a thousand feet high from the surface of Menippe, and now here I actually am on Menippe. I'll jump."

The sensation of that glorious rise skyward was delightful beyond expression. My legs seemed to have become as powerful as the engines of a transatlantic liner, and with one spring I rose smoothly and swiftly, and as straight as an arrow, surmounting the giant's foot, passing his knee and attaining nearly to the level of his hip. Then I felt that the momentum of my leap was exhausted, and despite my efforts I slowly turned head downward, glancing in affright at the ground a quarter of a mile below me, on which I expected to be dashed to pieces. But a moment's thought convinced me that I should get no hurt, for with so slight a force of gravity it would be more like floating than falling. Just then the Menippean caught me with his monstrous hand and lifted me to the level of his face.

"I should like to know," I said, "how you manage to live up here; you are so large and your planet is so little."

"Now, you are altogether too inquisitive," replied the giant. "You go!"

He stooped down, placed me on the toe of his boot, and drew back his foot to kick me off.

It flashed into my mind that my situation had now become very serious. I knew well what the effects of the small attractive force of these diminutive planets must be, for I had often amused myself with calculations about them. In this moment of peril I did not forget my mathematics. It was clear that if the giant propelled me with sufficient velocity I should be shot into space, never to return. How great would that velocity have to be? My mind worked like lightning on this problem. The diameter of Menippe I knew did not exceed twelve miles. Its mean density, as near as I could judge, was about the same as that of the earth. Its attraction must therefore be as its radius, or nearly 660 times less than that of the earth. A well-known formula enables us to compute the velocity a body would acquire in falling from an infinite distance to the earth or any other planet whose size and force of gravity are known. The same formula, taken in the opposite sense, of course, shows how fast a body must start from a planet in order that it may be freed from its control. The formula is $V = \sqrt{2gr}$., in which "g" is the acceleration of gravity, equal for the earth to 32 feet in a second, and "r" is the radius of the attracting body. On Menippe I knew "g" must equal about one twentieth of a foot, and "r" 31,680 feet. Like a flash I applied the formula while the giant's muscles were yet tightening for the kick: $31{,}680 \times 1/20 \times 2 = 3{,}168$, the square root of which is a fraction more than 56. Fifty-six feet in a second, then, was the critical velocity with which I must be kicked off in order that I might never return. I perceived at once that the giant would be able to accomplish it. I turned and shouted up at him:

“Hold on, I have something to say to you!”

I dimly saw his mountainous face puckered into mighty wrinkles, out of which his eyes glared fiercely, and the next moment I was sailing into space. I could no more have kept a balance than the earth can stand still upon its axis. I had become a small planet myself, and, like all planets, I rotated. Yet the motion did not dizzy me, and soon I became intensely interested in the panorama of creation that was spread around me. For some time, whenever my face was turned toward the little globe of Menippe, I saw the giant, partly in profile against the sky, with his back bent and his hands upon his knees, watching me with an occasional approving nod of his big head. He looked so funny standing there on his little seven-by-nine world, like a clown on a performing ball, that, despite my terrible situation, I shook my sides with laughter. There was no echo in the profundity of empty space.

Soon Menippe dwindled to a point, and I saw her inhospitable inhabitant no more. Then I watched the sun and the blazing firmament around, for there was at the same time broad day and midnight for me. The sunlight, being no longer diffused by an atmosphere, did not conceal the face of the sky, and I could see the stars shining close to the orb of day. I recognized the various planets much more easily than I had been accustomed to do, and, with a twinge at my heart, saw the earth traveling along in its distant orbit, splendid in the sunshine. I thought of my wife sitting alone by the telescope in the darkness and silence, wondering what had become of me. I asked myself, “How in the world can I ever get back there again?” Then I smiled to think of the ridiculous figure I cut, out here in space, exposed to the eyes of the universe, a rotating, gyrating, circumambulating astronomer, an animated teetotum lost in the sky. I saw no reason to hope that I should not go on thus forever, revolving around the sun until my bones, whitening among the stars, might be revealed to the superlative powers of some future telescope, and become a subject of absorbing interest, the topic of many a learned paper for the astronomers of a future age. Afterward I was comforted by the reflection that in airless space, although I might die and my body become desiccated, yet there could be no real decay; even my garments would probably last forever. The *savants*, after all, should never speculate on my bones.

I saw the ruddy disk of Mars, and the glinting of his icy poles, as the beautiful planet rolled far below me. “If I could only get there,” I thought, “I should know what those canals of Schiaparelli are, and even if I could never return to the earth, I should doubtless meet with a warm welcome among the Martians. What a lion I should be!” I looked longingly at the distant planet, the outlines of whose continents and seas appeared most enticing, but when I tried to propel myself in that direction I only kicked against nothingness. I groaned in desperation.

Suddenly something darted by me flying sunward; then another and another. In a minute I was surrounded by strange projectiles. Every instant I expected to be dashed in pieces by them. They sped with the velocity of lightning. Hundreds, thousands of them were all about me. My chance of not being hit was not one in a million, and yet I escaped. The sweat of terror was upon me, but I did not lose my head. “A comet has met me,” I said.

“These missiles are the meteoric stones of which it is composed.” And now I noticed that as they rushed along collisions took place, and flashes of electricity darted from one to another. A pale luminosity dimmed the stars. I did not doubt that, as seen from the earth, the comet was already flinging the splendors of its train upon the bosom of the night.

While I was wondering at my immunity amid such a rain of death-threatening bolts, I became aware that their velocity was sensibly diminishing. This fact I explained by supposing that I was drawn along with them. Notwithstanding the absence of any collision with my body, the overpowering attraction of the whole mass of meteors was overcoming my tangential force and bearing me in their direction. At first I rejoiced at this circumstance, for at any rate the comet would save me from the dreadful fate of becoming an asteroid. A little further reflection, however, showed me that I had gone from the frying-pan into the fire. The direction of my expulsion from Menippe had been such that I had fallen into an orbit that would have carried me around the sun without passing very close to the solar body. Now, being swept along by the comet, whose perihelion probably lay in the immediate neighborhood of the sun, I saw no way of escape from the frightful fate of being broiled alive. Even where I was, the untempered rays of the sun scorched me, and I knew that within two or three hundred thousand miles of the solar surface the heat must be sufficient to melt the hardest rocks. I was aware that experiments with burning-glasses had sufficiently demonstrated that fact.

But perforce I resigned myself to my fate. At any rate it would the sooner be all over. In fact, I almost forgot my awful situation in the interest awakened by the phenomena of the comet. I was in the midst of its very head. I was one of its component particles. I was a meteor among a million millions of others. If I could only get back to the earth, what news could I not carry to Signor Schiaparelli and Mr. Lockyer and Dr. Bredichin about the composition of comets! But, alas! the world could never know what I now saw. Nobody on yonder gleaming earth, watching the magnificent advance of this “specter of the skies,” would ever dream that there was a lost astronomer in its blazing head. I should be burned and rent to pieces amid the terrors of its perihelion passage, and my fragments would be strewn along the comet’s orbit, to become, in course of time, particles in a swarm of aerolites. Perchance, through the effects of some unforeseen perturbation, the earth might encounter that swarm. Thus only could I ever return to the bosom of my mother planet. I took a positive pleasure in imagining that one of my calcined bones might eventually flash for a moment, a falling star, in the atmosphere of the earth, leaving its atoms to slowly settle through the air, until finally they rested in the soil from which they had sprung.

From such reflections I was aroused by the approach of the crisis. The head of the comet had become an exceedingly uncomfortable place. The collisions among the meteors were constantly increasing in number and violence. How I escaped destruction I could not comprehend, but in fact I was unconscious of danger from that source. I had become in spirit an actual component of the clashing, roaring mass. Tremendous sparks of electricity, veritable lightning strokes, darted about me in every direction, but I bore a charmed life. As the comet drew in nearer to the sun, under the terrible stress of the solar attraction, the meteors seemed to crowd closer, crashing and grinding together, while the whole mass swayed and shrieked with the uproar of a million tormented devils. The heat had become terrific. I saw stone and iron melted like snow and dissipated in steam. Stupendous jets of white-hot vapor shot upward, and, driven off by the electrical repulsion of the sun, streamed backward into the tail.

Suddenly I myself became sensible of the awful heat. It seemed without warning to have penetrated my vitals. With a yell I jerked my feet from a boiling rock and flung my arms despairingly over my head.

“You had better be careful,” said my wife, “or you’ll knock over the telescope.”

I rubbed my eyes, shook myself, and rose.

“I must have been dreaming,” I said.

“I should think it was a very lively dream,” she replied.

I responded after the manner of a young man newly wed.

At this moment the occultation began.

CHAPTER VI

JUPITER, THE GREATEST OF KNOWN WORLDS

When we are thinking of worlds, and trying to exalt the imagination with them, it is well to turn to Jupiter, for there is a planet worth pondering upon! A world thirteen hundred times as voluminous as the earth is a phenomenon calculated to make us feel somewhat as the inhabitant of a rural village does when his amazed vision ranges across the million roofs of a metropolis. Jupiter is the first of the outer and greater planets, the major, or Jovian, group. His mean diameter is 86,500 miles, and his average girth more than 270,000 miles. An inhabitant of Jupiter, in making a trip around his planet, along any great circle of the sphere, would have to travel more than 30,000 miles farther than the distance between the earth and the moon. The polar compression of Jupiter, owing to his rapid rotation, amounts in the aggregate to more than 5,000 miles, the equatorial diameter being 88,200 miles and the polar diameter 83,000 miles.

Jupiter’s mean distance from the sun is 483,000,000 miles, and the eccentricity of his orbit is sufficient to make this distance variable to the extent of 21,000,000 miles; but, in view of his great average distance, the consequent variation in the amount of solar light and heat received by the planet is not of serious importance.

When he is in opposition to the sun as seen from the earth Jupiter’s mean distance from us is about 390,000,000 miles. His year, or period of revolution about the sun, is somewhat less than twelve of our years (11.86 years). His axis is very nearly upright to the plane of his orbit, so that, as upon Venus, there is practically no variation of seasons. Gigantic though he is in dimensions, Jupiter is the swiftest of all the planets in axial rotation. While the earth requires twenty-four hours to make a complete turn, Jupiter takes less than ten hours (nine hours fifty-five minutes), and a point on his equator moves, in consequence of axial rotation, between 27,000 and 28,000 miles in an hour.

The density of the mighty planet is slight, only about one quarter of the mean density of the earth and virtually the same as that of the sun. This fact at once calls attention to a contrast between Jupiter and our globe that is even more significant than their immense difference in size. The force of gravity upon Jupiter’s surface is more than two and a half times greater than upon the earth’s surface (more accurately 2.65 times), so that a hundred-pound weight removed from the planet on which we live to Jupiter would there weigh 265 pounds, and an average man, similarly transported, would be oppressed with a weight of at least 400 pounds. But, as a result of the rapid rotation of the great planet, and the ellipticity of its figure, the unfortunate visitor could find a perceptible relief from his troublesome weight by seeking the planet’s equator, where the centrifugal tendency would remove about twenty pounds from every one hundred as compared with his weight at the poles.

If we could go to the moon, or to Mercury, Venus, or Mars, we may be certain that upon reaching any of those globes we should find ourselves upon a solid surface, probably composed of rock not unlike the rocky crust of the earth; but with Jupiter the case would evidently be very different. As already remarked, the mean density of that planet is only one quarter of the earth’s density, or only one third greater than the density of water. Consequently the visitor, in attempting to set foot upon Jupiter, might find no solid supporting surface, but would be in a situation as embarrassing as that of Milton's Satan when he undertook to cross the domain of Chaos:

> “Fluttering his pinions vain, plumb down he drops,
> Ten thousand fathom deep, and to this hour
> Down had been falling had not, by ill chance,
> The strong rebuff of some tumultuous cloud.
> Instinct with fire and niter, hurried him
> As many miles aloft; that fury stayed,
> Quenched in a boggy Syrtis, neither sea
> Nor good dry land, nigh foundered, as he fares,
> Treading the crude consistence, half on foot,
> Half flying.”

The probability that nothing resembling a solid crust, nor, perhaps, even a liquid shell, would be found at the visible surface of Jupiter, is increased by considering that the surface density must be much less than the mean density of the planet taken as a whole, and since the latter but little exceeds the density of water, it is likely that at the surface everything is in a state resembling that of cloud or smoke. Our imaginary visitor upon reaching Jupiter would, under the influence of the planet’s strong force of gravity, drop out of sight, with the speed of a shot, swallowed up in the vast atmosphere of probably hot, and perhaps partially incandescent, gases. When he had sunk—supposing his identity could be preserved—to a depth of thousands of miles he might not yet have found any solid part of the planet; and, perchance, there is no solid nucleus even at the very center.

The cloudy aspect of Jupiter immediately strikes the telescopic observer. The huge planet is filled with color, and with the animation of constant movement, but there is no appearance of markings, like those on Mars, recalling the look of the earth. There are no white polar caps, and no shadings that suggest the outlines of continents and oceans. What every observer, even with the smallest telescope, perceives at once is a pair of strongly defined dark belts, one on either side of, and both parallel to, the planet’s equator. These belts are dark compared with the equatorial band between them and with the general surface of the planet toward the north and the south, but they are not of a gray or neutral shade. On the contrary, they show decided, and, at times, brilliant colors, usually of a reddish tone. More delicate tints, sometimes a fine pink, salmon, or even light green, are occasionally to be seen about the equatorial zone, and the borders of the belts, while near the poles the surface is shadowed with bluish gray, imperceptibly deepening from the lighter hues of the equator.

All this variety of tone and color makes of a telescopic view of Jupiter a picture that will not quickly fade from the memory; while if an instrument of considerable power is used, so that the wonderful details of the belts, with their scalloped edges, their diagonal filaments, their many divisions, and their curious light and dark spots, are made plain, the observer is deeply impressed with the strangeness of the spectacle, and the more so as he reflects upon the enormous real magnitude of that which is spread before his eye. The whole earth flattened out would be but a small blotch on that gigantic disk!

Then, the visible rotation of the great Jovian globe, whose effects become evident to a practised eye after but a few minutes’ watching, heightens the impression. And the presence of the four satellites, whose motions in their orbits are also evident, through the change in their positions, during the course of a single not prolonged observation, adds its influence to the effectiveness of the scene. Indeed, color and motion are so conspicuous in the immense spectacle presented by Jupiter that they impart to it a powerful suggestion of life, which the mind does not readily divest itself of when compelled to face the evidence that Jupiter is as widely different from the earth, and as diametrically opposed to lifelike conditions, as we comprehend them, as a planet possibly could be.

The great belts lie in latitudes about corresponding to those in which the trade-winds blow upon the earth, and it has often been suggested that their existence indicates a similarity between the atmospheric circulation of Jupiter and that of the world in which we live. No doubt there are times when the earth, seen with a telescope from a distant planet, would present a belted appearance somewhat resembling that of Jupiter, but there would almost certainly be no similar display of colors in the clouds, and the latter would exhibit no such persistence in general form and position as characterizes those of Jupiter. Our clouds are formed by the action of the sun, producing evaporation of water; on Jupiter, whose mean distance from the sun is more than five times as great as ours, the intensity of the solar rays is reduced to less than one twenty-fifth part of their intensity on the earth, so that the evaporation can not be equally active there, and the tendency to form aerial currents and great systems of winds must be proportionally slight. In brief, the clouds of Jupiter are probably of an entirely different origin from that of terrestrial clouds, and rather resemble the chaotic masses of vapor that enveloped the earth when it was still in a seminebulous condition, and before its crust had formed.

Although the strongest features of the disk of Jupiter are the great cloud belts, and the white or colored spots in the equatorial zone, yet the telescope shows many markings north and south of the belts, including a number of narrower and fainter belts, and small light or dark spots. None of them is absolutely fixed in position with reference to others. In other words, all of the spots, belts, and markings shift their places to a perceptible extent, the changes being generally very slow and regular, but occasionally quite rapid. The main belts never entirely disappear, and never depart very far from their mean positions with respect to the equator, but the smaller belts toward the north and south are more or less evanescent. Round or oblong spots, as distinguished from belts, are still more variable and transient. The main belts themselves show great internal commotion, frequently splitting up, through a considerable part of their length, and sometimes apparently throwing out projections into the lighter equatorial zone, which occasionally resemble bridges, diagonally spanning the broad space between the belts.

JUPITER AS SEEN AT THE LICK OBSERVATORY IN 1889. THE GREAT RED SPOT IS VISIBLE, TOGETHER WITH THE INDENTATION IN THE SOUTH BELT.

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Perhaps the most puzzling phenomenon that has ever made its appearance on Jupiter is the celebrated “great red spot,” which was first noticed in 1878, although it has since been shown to be probably identical with a similar spot seen in 1869, and possibly with one noticed in 1857. This spot, soon after its discovery in 1878, became a clearly defined red oval, lying near the southern edge of the south belt in latitude about 30°. Its length was nearly one third of the diameter of the disk and its width almost one quarter as great as its length. Translated into terrestrial measure, it was about 30,000 miles long and 7,000 miles broad.

In 1879 it seemed to deepen in color until it became a truly wonderful object, its redness of hue irresistibly suggesting the idea that it was something hot and glowing. During the following years it underwent various changes of appearance, now fading almost to invisibility and now brightening again, but without ever completely vanishing, and it is still (1901) faintly visible.

Nobody has yet suggested an altogether probable and acceptable theory as to its nature. Some have said that it might be a part of the red-hot crust of the planet elevated above the level of the clouds; others that its appearance might be due to the clearing off of the clouds above a heated region of the globe beneath, rendering the latter visible through the opening; others that it was perhaps a mass of smoke and vapor ejected from a gigantic volcano, or from the vents covering a broad area of volcanic action; others that it might be a vast incandescent slag floating upon the molten globe of the planet and visible through, or above, the enveloping clouds; and others have thought that it could be nothing but a cloud among clouds, differing, for unknown reasons, in composition and cohesion from its surroundings. All of these hypotheses except the last imply the existence, just beneath the visible cloud shell, of a more or less stable and continuous surface, either solid or liquid.

When the red spot began to lose distinctness a kind of veil seemed to be drawn over it, as if light clouds, floating at a superior elevation, had drifted across it. At times it has been reduced in this manner to a faint oval ring, the rim remaining visible after the central part has faded from sight.

One of the most remarkable phenomena connected with the mysterious spot is a great bend, or scallop, in the southern edge of the south belt adjacent to the spot. This looks as if it were produced by the spot, or by the same cause to which the spot owes its existence. If the spot were an immense mountainous elevation, and the belt a current of liquid, or of clouds, flowing past its base, one would expect to see some such bend in the stream. The visual evidence that the belt is driven, or forced, away from the neighborhood of the spot seems complete. The appearance of repulsion between them is very striking, and even when the spot fades nearly to invisibility the curve remains equally distinct, so that in using a telescope too small to reveal the spot itself one may discover its location by observing the bow in the south belt. The suggestion of a resemblance to the flowing of a stream past the foot of an elevated promontory, or mountain, is strengthened by the fact, which was observed early in the history of the spot, that markings involved in the south belt have a quicker rate of rotation about the planet’s axis than that of the red spot, so that such markings, first seen in the rear of the red spot, gradually overtake and pass it, and eventually leave it behind, as boats in a river drift past a rock lying in the midst of the current.

This leads us to another significant fact concerning the peculiar condition of Jupiter’s surface. Not only does the south belt move perceptibly faster than the red spot, but, generally speaking, the various markings on the surface of the planet move at different rates according as they are nearer to or farther from the equator. Between the equator and latitude 30° or 40° there is a difference of six minutes in the rotation period—i.e., the equatorial parts turn round the axis so much faster than the parts north and south of them, that in one rotation they gain six minutes of time. In other words, the clouds over Jupiter's equator flow past those in the middle latitudes with a relative velocity of 270 miles per hour. But there are no sharp lines of separation between the different velocities; on the contrary, the swiftness of rotation gradually diminishes from the equator toward the poles, as it manifestly could not do if the visible surface of Jupiter were solid.

In this respect Jupiter resembles the sun, whose surface also has different rates of rotation diminishing from the equator. Measured by the motion of spots on or near the equator, Jupiter's rotation period is about nine hours fifty minutes; measured by the motion of spots in the middle latitudes, it is about nine hours fifty-six minutes. The red spot completes a rotation in a little less than nine hours and fifty-six minutes, but its period can not be positively given for the singular reason that it is variable. The variation amounts to only a few seconds in the course of several years, but it is nevertheless certain. The phenomenon of variable motion is not, however, peculiar to the red spot. Mr. W.F. Denning, who has studied Jupiter for a quarter of a century, says:

"It is well known that in different latitudes of Jupiter there are currents, forming the belts and zones, moving at various rates of speed. In many instances the velocity changes from year to year. And it is a singular circumstance that in the same current a uniform motion is not maintained in all parts of the circumference. Certain spots move faster than others, so that if we would obtain a fair value for the rotation period of any current it is not sufficient to derive it from one marking alone; we must follow a number of objects distributed in different longitudes along the current and deduce a mean from the whole."[10]

Nor is this all. Observation indicates that if we could look at a vertical section of Jupiter's atmosphere we should behold an equally remarkable contrast and conflict of motions. There is evidence that some of the visible spots, or clouds, lie at a greater elevation than others, and it has been observed that the deeper ones move more rapidly. This fact has led some observers to conclude that the deep-lying spots may be a part of the actual surface of the planet. But if we could think that there is any solid nucleus, or core, in the body of Jupiter, it would seem, on account of the slight mean density of the planet, that it can not lie so near the visible surface, but must be at a depth of thousands, perhaps tens of thousands, of miles. Since the telescope is unable to penetrate the cloudy envelope we can only guess at the actual constitution of the interior of Jupiter's globe. In a spirit of mere speculative curiosity it has been suggested that deep under the clouds of the great planet there may be a comparatively small solid globe, even a habitable world, closed round by a firmament all its own, whose vault, raised 30,000 or 40,000 miles above the surface of the imprisoned planet, appears only an unbroken dome, too distant to reveal its real nature to watchers below, except, perhaps, under telescopic scrutiny; enclosing, as in a shell, a transparent atmosphere, and deriving its illumination partly from the sunlight that may filter through, but mainly from some luminous source within.

But is not Jupiter almost equally fascinating to the imagination, if we dismiss all attempts to picture a humanly impossible world shut up within it, and turn rather to consider what its future may be, guided by the not unreasonable hypothesis that, because of its immense size and mass, it is still in a chaotic condition? Mention has been made of the resemblance of Jupiter to the sun by virtue of their similar manner of rotation. This is not the only reason for looking upon Jupiter as being, in some respects, almost as much a solar as a planetary body. Its exceptional brightness rather favors the view that a small part of the light by which it shines comes from its own incandescence. In size and mass it is half-way between the earth and the sun. Jupiter is eleven times greater than the earth in diameter and thirteen hundred times greater in volume; the sun is ten times greater than Jupiter in diameter and a thousand times greater in volume. The mean density of Jupiter, as we have seen, is almost exactly the same as the sun's.

Now, the history of the solar system, according to the nebular hypothesis, is a history of cooling and condensation. The sun, a thousand times larger than Jupiter, has not yet sufficiently cooled and contracted to become incrusted, except with a shell of incandescent metallic clouds; Jupiter, a thousand times smaller than the sun, has cooled and contracted until it is but slightly, if at all, incandescent at its surface, while its thickening shell, although still composed of vapor and smoke, and still probably hot, has grown so dense that it entirely cuts off the luminous radiation from within; the earth, to carry the comparison one step further, being more than a thousand times smaller than Jupiter, has progressed so far in the process of cooling that its original shell of vapor has given place to one of solid rock.

A sudden outburst of light from Jupiter, such as occurs occasionally in a star that is losing its radiance through the condensation of absorbing vapors around it, would furnish strong corroboration of the theory that Jupiter is really an extinguished sun which is now on the way to become a planet in the terrestrial sense.

Not very long ago, as time is reckoned in astronomy, our sun, viewed from the distance of the nearer fixed stars, may have appeared as a binary star, the brighter component of the pair being the sun itself and the fainter one the body now called the planet Jupiter. Supposing the latter to have had the same intrinsic brilliance, surface for surface, as the sun, it would have radiated one hundred times less light than the sun. A difference of one hundredfold between the light of two stars means that they are six magnitudes apart; or, in other words, from a point in space where the sun appeared as bright as what we call a first-magnitude star, its companion, Jupiter, would have shone as a sixth-magnitude star. Many stars have companions proportionally much fainter than that. The companion of Sirius, for instance, is at least ten thousand times less bright than its great comrade.

Looking at Jupiter in this way, it interests us not as the probable abode of intelligent life, but as a world in the making, a world, moreover, which, when it is completed—if it ever shall be after the terrestrial pattern—will dwarf our globe into insignificance. That stupendous miracle of world-making which is dimly painted in the grand figures employed by the writers of Genesis, and the composers of other cosmogonic legends, is here actually going on before our eyes. The telescope shows us in the cloudy face of Jupiter the moving of the spirit upon the face of the great deep. What the final result will be we can not tell, but clearly the end of the grand processes there in operation has not yet been reached.

The interesting suggestion was made and urged by Mr. Proctor that if Jupiter itself is in no condition at present to bear life, its satellites may be, in that respect, more happily circumstanced. It can not be said that very much has been learned about the satellites of Jupiter since Proctor's day, and his suggestion is no less and no more probable now than it was when first offered.

There has been cumulative evidence that Jupiter’s satellites obey the same law that governs the rotation of our moon, viz., that which compels them always to keep the same face turned toward their primary, and this would clearly affect, although it might not preclude, their habitability. With the exception of the minute fifth satellite discovered by Barnard in 1892, they are all of sufficient size to retain at least some traces of an atmosphere. In fact, one of them is larger than the planet Mars, and another is of nearly the same size as that planet, while the smallest of the four principal ones is about equal to our moon. Under the powerful attraction of Jupiter they travel rapidly, and viewed from the surface of that planet they would offer a wonderful spectacle.

They are continually causing solar eclipses and themselves undergoing eclipse in Jupiter’s shadow, and their swiftly changing aspects and groupings would be watched by an astronomer on Jupiter with undying interest.

But far more wonderful would be the spectacle presented by Jupiter to inhabitants dwelling on his moons. From the nearer moon, in particular, which is situated less than 220,000 miles from Jupiter’s surface, the great planet would be an overwhelming phenomenon in the sky.

Its immense disk, hanging overhead, would cover a circle of the firmament twenty degrees in diameter, or, in round numbers, forty times the diameter of the full moon as seen from the earth! It would shed a great amount of light and heat, and thus would more or less effectively supply the deficit of solar radiation, for we must remember that Jupiter and his satellites receive from the sun less than one twenty-fifth as much light and heat as the earth receives.

The maze of contending motions, the rapid flow and eddying of cloud belts, the outburst of strange fiery spots, the display of rich, varied, and constantly changing colors, which astonish and delight the telescopic observer on the earth, would be exhibited to the naked eye of an inhabitant of Jupiter’s nearest moon far more clearly than the greatest telescope is able to reveal them to us.

Here, again, the mind is carried back to long past ages in the history of the planet on which we dwell. It is believed by some that our moon may have contained inhabitants when the earth was still hot and glowing, as Jupiter appears to be now, and that, as the earth cooled and became habitable, the moon gradually parted with its atmosphere and water so that its living races perished almost coincidently with the beginning of life on the earth. If we accept this view and apply it to the case of Jupiter we may conclude that when that enormous globe has cooled and settled down to a possibly habitable condition, its four attendant moons will suffer the fate that overtook the earth’s satellite, and in their turn become barren and death-stricken, while the great orb that once nurtured them with its light and heat receives the Promethean fire and begins to bloom with life.

CHAPTER VII

SATURN, A PRODIGY AMONG PLANETS

One of the first things that persons unaccustomed to astronomical observations ask to see when they have an opportunity to look through a telescope is the planet Saturn. Many telescopic views in the heavens disappoint the beginner, but that of Saturn does not. Even though the planet may not look as large as he expects to see it from what he has been told of the magnifying power employed, the untrained observer is sure to be greatly impressed by the wonderful rings, suspended around it as if by a miracle. No previous inspection of pictures of these rings can rob them of their effect upon the eye and the mind. They are overwhelming in their inimitable singularity, and they leave every spectator truly amazed. Sir John Herschel has remarked that they have the appearance of an “elaborately artificial mechanism.” They have even been regarded as habitable bodies! What we are to think of that proposition we shall see when we come to consider their composition and probable origin. In the meantime let us recall the main facts of Saturn’s dimensions and situation in the solar system.

Saturn is the second of the major, or Jovian, group of planets, and is situated at a mean distance from the sun of 886,000,000 miles. We need not consider the eccentricity of its orbit, which, although relatively not very great, produces a variation of 50,000,000 miles in its distance from the sun, because, at its immense mean distance, this change would not be of much importance with regard to the planet’s habitability or non-habitability. Under the most favorable conditions Saturn can never be nearer than 744,000,000 miles to the earth, or eight times the sun’s distance from us. It receives from the sun about one ninetieth of the light and heat that we get.

SATURN IN ITS THREE PRINCIPAL PHASES AS SEEN FROM THE EARTH. From a drawing by Bond.

SATURN IN ITS THREE PRINCIPAL PHASES AS SEEN FROM THE EARTH. From a drawing by Bond.

Saturn takes twenty-nine and a half years to complete a journey about the sun. Like Jupiter, it rotates very rapidly on its axis, the period being ten hours and fourteen minutes. Its axis of rotation is inclined not far from the same angle as that of the earth’s axis (26° 49′), so that its seasons should resemble ours, although their alternations are extremely slow in consequence of the enormous length of Saturn’s year.

Not including the rings in the calculation, Saturn exceeds the earth in size 760 times. The addition of the rings would not, however, greatly alter the result of the comparison, because, although the total surface of the rings, counting both faces, exceeds the earth’s surface about 160 times, their volume, owing to their surprising thinness, is only about six times the volume of the earth, and their mass, in consequence of their slight density, is very much less than the earth’s, perhaps, indeed, inappreciable in comparison.

Saturn’s mean diameter is 73,000 miles, and its polar compression is even greater than that of Jupiter, a difference of 7,000 miles—almost comparable with the entire diameter of the earth—existing between its equatorial and its polar diameter, the former being 75,000 and the latter 68,000 miles.

We found the density of Jupiter astonishingly slight, but that of Saturn is slighter still. Jupiter would sink if thrown into water, but Saturn would actually float, if not "like a cork," yet quite as buoyantly as many kinds of wood, for its mean density is only three quarters that of water, or one eighth of the earth's. In fact, there is no known planet whose density is so slight as Saturn's. Thus it happens that, notwithstanding its vast size and mass, the force of gravity upon Saturn is nearly the same as upon our globe. Upon visiting Venus we should find ourselves weighing a little less than at home, and upon visiting Saturn a little more, but in neither case would the difference be very important. If the relative weight of bodies on the surfaces of planets formed the sole test of their habitability, Venus and Saturn would both rank with the earth as suitable abodes for men.

But the exceedingly slight density of Saturn seems to be most reasonably accounted for on the supposition that, like Jupiter, it is in a vaporous condition, still very hot within—although but slightly, if at all, incandescent at the surface—and, therefore, unsuited to contain life. It is hardly worth while to speculate about any solid nucleus within, because, even if such a thing were possible, or probable, it must lie forever hidden from our eyes. But if we accept the theory that Saturn is in an early formative stage, and that, millions of years hence, it may become an incrusted and habitable globe, we shall, at least, follow the analogy of what we believe to have been the history of the earth, except that Saturn's immense distance from the sun will always prevent it from receiving an amount of solar radiation consistent with our ideas of what is required by a living world. Of course, since one can imagine what he chooses, it is possible to suppose inhabitants suited to existence in a world composed only of whirling clouds, and a poet with the imagination of a Milton might give us very imposing and stirring images of such creatures and their chaotic surroundings, but fancies like these can have no basis in human experience, and consequently can make no claim upon scientific recognition.

Or, as an alternative, it might be assumed that Saturn is composed of lighter elements and materials than those which constitute the earth and the other solid planets in the more immediate neighborhood of the sun. But such an assumption would put us entirely at sea as regards the forms of organic life that could exist upon a planet of that description, and, like Sir Humphry Davy in the Vision, that occupies the first chapter of his quaintly charming Consolations in Travel, or, the Last Days of a Philosopher, we should be thrown entirely upon the resources of the imagination in representing to ourselves the nature and appearance of its inhabitants. Yet minds of unquestioned power and sincerity have in all ages found pleasure and even profit in such exercises, and with every fresh discovery arises a new flight of fancies like butterflies from a roadside pool. As affording a glimpse into the mind of a remarkable man, as well as a proof of the fascination of such subjects, it will be interesting to quote from the book just mentioned Davy's description of his imaginary inhabitants of Saturn:

"I saw below me a surface infinitely diversified, something like that of an immense glacier covered with large columnar masses, which appeared as if formed of glass, and from which were suspended rounded forms of various sizes which, if they had not been transparent, I might have supposed to be fruit. From what appeared to me to be analogous to bright-blue ice, streams of the richest tint of rose color or purple burst forth and flowed into basins, forming lakes or seas of the same color. Looking through the atmosphere toward the heavens, I saw brilliant opaque clouds, of an azure color, that reflected the light of the sun, which had to my eyes an entirely new aspect and appeared smaller, as if seen through a dense blue mist.

"I saw moving on the surface below me immense masses, the forms of which I find it impossible to describe. They had systems for locomotion similar to those of the morse, or sea-horse, but I saw, with great surprise, that they moved from place to place by six extremely thin membranes, which they used as wings. Their colors were varied and beautiful, but principally azure and rose color. I saw numerous convolutions of tubes, more analogous to the trunk of the elephant than to anything else I can imagine, occupying what I supposed to be the upper parts of the body. It was with a species of terror that I saw one of them mounting upward, apparently flying toward those opaque clouds which I have before mentioned.

"'I know what your feelings are,' said the Genius; 'you want analogies, and all the elements of knowledge to comprehend the scene before you. You are in the same state in which a fly would be whose microscopic eye was changed for one similar to that of man, and you are wholly unable to associate what you now see with your former knowledge. But those beings who are before you, and who appear to you almost as imperfect in their functions as the zoophytes of the polar sea, to which they are not unlike in their apparent organization to your eyes, have a sphere of sensibility and intellectual enjoyment far superior to that of the inhabitants of your earth. Each of those tubes, which appears like the trunk of an elephant, is an organ of peculiar motion or sensation. They have many modes of perception of which you are wholly ignorant, at the same time that their sphere of vision is infinitely more extended than yours, and their organs of touch far more perfect and exquisite.'"

After descanting upon the advantages of Saturn's position for surveying some of the phenomena of the solar system and of outer space, and the consequent immense advances that the Saturnians have made in astronomical knowledge, the Genius continues:

"'If I were to show you the different parts of the surface of this planet you would see the marvelous results of the powers possessed by these highly intellectual beings, and of the wonderful manner in which they have applied and modified matter. Those columnar masses, which seem to you as if rising out of a mass of ice below, are results of art, and processes are going on within them connected with the formation and perfection of their food. The brilliant-colored fluids are the results of such operations as on the earth would be performed in your laboratories, or more properly in your refined culinary apparatus, for they are connected with their system of nourishment. Those opaque azure clouds, to which you saw a few minutes ago one of those beings directing his course, are works of art, and places in which they move through different regions of their atmosphere, and command the temperature and the quantity of light most fitted for their philosophical researches, or most convenient for the purposes of life.'"[11]

But, while Saturn does not appear, with our present knowledge, to hold out any encouragement to those who would regard it as the abode of living creatures capable of being described in any terms except those of pure imagination, yet it is so unique a curiosity among the heavenly bodies that one returns again and again to the contemplation of its strange details. Saturn has nine moons, but some of them are relatively small bodies —the ninth, discovered photographically by Professor Pickering in 1899, being especially minute—and others are situated at great distances from the planet, and for these reasons, together with the fact that the sunlight is so feeble upon them that, surface for surface, they have only one ninetieth as much illumination as our moon receives, they can not make a very brilliant display in the Saturnian sky. To astronomers on Saturn they would, of course, be intensely interesting because of their perturbations and particularly the effect of their attraction on the rings.

This brings us again to the consideration of those marvelous appendages, and to the statement of facts about them which we have not yet recalled.

If the reader will take a ball three inches in diameter to represent the globe of Saturn, and, out of the center of a circular piece of writing-paper seven inches in diameter, will cut a round hole three and three quarter inches across, and will then place the ball in the middle of the hole in the paper, he will have a very fair representation of the relative proportions of Saturn and its rings. To represent the main gap or division in the rings he might draw, a little more than three eighths of an inch from the outer edge of the paper disk, a pencil line about a sixteenth of an inch broad.

Perhaps the most striking fact that becomes conspicuous in making such a model of the Saturnian system is the exceeding thinness of the rings as compared with their enormous extent. They are about 170,000 miles across from outer edge to outer edge, and about 38,000 miles broad from outer edge to inner edge—including the gauze ring presently to be mentioned—yet their thickness probably does not surpass one hundred miles! In fact, the sheet of paper in our imaginary model is several times too thick to represent the true relative thickness of Saturn’s rings.

Several narrow gaps in the rings have been detected from time to time, but there is only one such gap that is always clearly to be seen, the one already mentioned, situated about 10,000 miles from the outer edge and about 1,600 miles in width. Inside of this gap the broadest and brightest ring appears, having a width of about 16,500 miles. For some reason this great ring is most brilliant near the gap, and its brightness gradually falls off toward its inner side. At a distance of something less than 20,000 miles from the planet—or perhaps it would be more correct to say above the planet, for the rings hang directly over Saturn’s equator—the broad, bright ring merges into a mysterious gauzelike object, also in the form of a ring, which extends to within 9,000 or 10,000 miles of the planet’s surface, and therefore itself has a width of say 10,000 miles.

In consequence of the thinness of the rings they completely disappear from the range of vision of small telescopes when, as occurs once in every fifteen years, they are seen exactly edgewise from the earth. In a telescope powerful enough to reveal them when in that situation they resemble a thin, glowing needle run through the ball of the planet. The rings will be in this position in 1907, and again in 1922.

The opacity of the rings is proved by the shadow which they cast upon the ball of the planet. This is particularly manifest at the time when they are edgewise to the earth, for the sun being situated slightly above or below the plane of the rings then throws their shadow across Saturn close to its equator. When they are canted at a considerable angle to our line of sight their shadow is seen on the planet, bordering their outer edge where they cross the ball.

The gauze ring, the detection of which as a faintly luminous phenomenon requires a powerful telescope, can be seen with slighter telescopic power in the form of a light shade projected against the planet at the inner edge of the broad bright ring. The explanation of the existence of this peculiar object depends upon the nature of the entire system, which, instead of being, as the earliest observers thought it, a solid ring or series of concentric rings, is composed of innumerable small bodies, like meteorites, perhaps, in size, circulating independently but in comparatively close juxtaposition to one another about Saturn, and presenting to our eyes, because of their great number and of our enormous distance, the appearance of solid, uniform rings. So a flock of ducks may look from afar like a continuous black line or band, although if we were near them we should perceive that a considerable space separates each individual from his neighbors.

The fact that this is the constitution of Saturn's rings can be confidently stated because it has been mathematically proved that they could not exist if they were either solid or liquid bodies in a continuous form, and because the late Prof. James E. Keeler demonstrated with the spectroscope, by means of the Doppler principle, already explained in the chapter on Venus, that the rings circulate about the planet with varying velocities according to their distance from Saturn's center, exactly as independent satellites would do.

It might be said, then, that Saturn, instead of having nine satellites only, has untold millions of them, traveling in orbits so closely contiguous that they form the appearance of a vast ring.

As to their origin, it may be supposed that they are a relic of a ring of matter left in suspension during the contraction of the globe of Saturn from a nebulous mass, just as the rings from which the various planets are supposed to have been formed were left off during the contraction of the main body of the original solar nebula. Other similar rings originally surrounding Saturn may have become satellites, but the matter composing the existing rings is so close to the planet that it falls within the critical distance known as "Roche's limit," within which, owing to the tidal effect of the planet's attraction, no body so large as a true satellite could exist, and accordingly in the process of formation of the Saturnian system this matter, instead of being aggregated into a single satellite, has remained spread out in the form of a ring, although its substance long ago passed from the vaporous and liquid to the solid form. We have spoken of the rings as being composed of meteorites, but perhaps their component particles may be so small as to answer more closely to the definition of dust. In these rings of dust, or meteorites, disturbances are produced by the attraction of the planet and that of the outer satellites, and it is yet a question whether they are a stable and permanent feature of Saturn, or will, in the course of time, be destroyed.[12]

It has been thought that the gauze ring is variable in brightness. This would tend to show that it is composed of bodies which have been drawn in toward the planet from the principal mass of the rings, and these bodies may end their career by falling upon the planet. This process, indefinitely continued, would result in the total disappearance of the rings—Saturn would finally swallow them, as the old god from whom the planet gets its name is fabled to have swallowed his children.

Near the beginning of this chapter reference was made to the fact that Saturn's rings have been regarded as habitable bodies. That, of course, was before the discovery that they were not solid. Knowing what we now know about them, even Dr. Thomas Dick, the great Scotch popularizer of astronomy in the first half of the nineteenth century, would have been compelled to abandon his theory that Saturn's rings were crowded with inhabitants. At the rate of 280 to the square mile he reckoned that they could easily contain 8,078,102,266,080 people.

He even seems to have regarded their edges—in his time their actual thinness was already well known—as useful ground for the support of living creatures, for he carefully calculated the aggregate area of these edges and found that it considerably exceeded the area of the entire surface of the earth. Indeed, Dr. Dick found room for more inhabitants on Saturn's rings than on Saturn itself, for, excluding the gauze ring, undiscovered in his day, the two surfaces of the rings are greater in area than the surface of the globe of the planet. He did not attack the problem of the weight of bodies on worlds in the form of broad, flat, thin, surfaces like Saturn's rings, or indulge in any reflections on the interrelations of the inhabitants of the opposite sides, although he described the wonderful appearance of Saturn and other celestial objects as viewed from the rings.

But all these speculations fall to the ground in face of the simple fact that if we could reach Saturn's rings we should find nothing to stand upon, except a cloud of swiftly flying dust or a swarm of meteors, swayed by contending attractions. And, indeed, it is likely that upon arriving in the immediate neighborhood of the rings they would virtually disappear! Seen close at hand their component particles might be so widely separated that all appearance of connection between them would vanish, and it has been estimated that from Saturn's surface the rings, instead of presenting a gorgeous arch spanning the heavens, may be visible only as a faintly gleaming band, like the Milky Way or the zodiacal light. In this respect the mystic Swedenborg appears to have had a clearer conception of the true nature of Saturn's rings than did Dr. Dick, for in his book on The Earths in the Universe he says—using the word "belt" to describe the phenomenon of the rings:

"Being questioned concerning that great belt which appears from our earth to rise above the horizon of that planet, and to vary its situations, they [the inhabitants of Saturn] said that it does not appear to them as a belt, but only as somewhat whitish, like snow in the heaven, in various directions."

In view of such observations as that of Prof. E.E. Barnard, in 1892, showing that a satellite passing through the shadow of Saturn's rings does not entirely disappear—a fact which proves that the rings are partially transparent to the sunlight—one might be tempted to ask whether Saturn itself, considering its astonishing lack of density, is not composed, at least in its outer parts, of separate particles of matter revolving independently about their center of attraction, and presenting the appearance of a smooth, uniform shell reflecting the light of the sun. In other words, may not Saturn be, exteriorly, a globe of dust instead of a globe of vapor? Certainly the rings, incoherent and translucent though they be, reflect the sunlight to our eyes, at least from the brighter part of their surface, with a brilliance comparable with that of the globe of the planet itself.

As bearing on the question of the interior condition of Saturn and Jupiter, it should, perhaps, be said that mathematical considerations, based on the figures of equilibrium of rotating liquid masses, lead to the conclusion that those planets are comparatively very dense within. Professor Darwin puts the statement very strongly, as follows: "In this way it is known with certainty that the central portions of the planets Jupiter and Saturn are much denser, compared to their superficial portions, than is the case with the earth."[13]

The globe and rings of Saturn witness an imposing spectacle of gigantic moving shadows. The great ball stretches its vast shade across the full width of the rings at times, and the rings, as we have seen, throw their shadow in a belt, whose position slowly changes, across the ball, sweeping from the equator, now toward one pole and now toward the other. The sun shines alternately on each side of the rings for a space of nearly fifteen years—a day fifteen years long! And then, when that face of the ring is turned away from the sun, there ensues a night of fifteen years' duration also.

Whatever appearance the rings may present from the equator and the middle latitudes on Saturn, from the polar regions they would be totally invisible. As one passed toward the north, or the south, pole he would see the upper part of the arch of the rings gradually sink toward the horizon until at length, somewhere in the neighborhood of the polar circle, it would finally disappear, hidden by the round shoulder of the great globe.

URANUS, NEPTUNE, AND THE SUSPECTED ULTRANEPTUNIAN PLANET

What has been said of Jupiter and Saturn applies also to the remaining members of the Jovian group of planets, Uranus and Neptune, viz., that their density is so small that it seems probable that they can not, at the present time, be in a habitable planetary condition. All four of these outer, larger planets have, in comparatively recent times, been solar orbs, small companions of the sun. The density of Uranus is about one fifth greater than that of water, and slightly greater than that of Neptune. Uranus is 32,000 miles in diameter, and Neptune 35,000 miles. Curiously enough, the force of gravity upon each of these two large planets is a little less than upon the earth. This arises from the fact that in reckoning gravity on the surface of a planet not only the mass of the planet, but its diameter or radius, must be considered. Gravity varies directly as the mass, but inversely as the square of the radius, and for this reason a large planet of small density may exercise a less force of gravity at its surface than does a small planet of great density.

The mean distance of Uranus from the sun is about 1,780,000,000 miles, and its period of revolution is eighty-four years; Neptune's mean distance is about 2,800,000,000 miles, and its period of revolution is about 164 years.

Uranus has four satellites, and Neptune one. The remarkable thing about these satellites is that they revolve *backward*, or contrary to the direction in which all the other satellites belonging to the solar system revolve, and in which all the other planets rotate on their axis. In the case of Uranus, the plane in which the satellites revolve is not far from a position at right angles to the plane of the ecliptic; but in the case of Neptune, the plane of revolution of the satellites is tipped much farther backward. Since in every other case the satellites of a planet are situated nearly in the plane of the planet's equator, it may be assumed that the same rule holds with Uranus and Neptune; and, that being so, we must conclude that those planets rotate backward on their axes. This has an important bearing on the nebular hypothesis of the origin of the solar system, and at one time was thought to furnish a convincing argument against that hypothesis; but it has been shown that by a modification of Laplace’s theory the peculiar behavior of Uranus and Neptune can be reconciled with it.

Very little is known of the surfaces of Uranus and Neptune. Indications of the existence of belts resembling those of Jupiter have been found in the case of both planets. There are similar belts on Saturn, and as they seem to be characteristic of large, rapidly rotating bodies of small density, it was to be expected that they would be found on Uranus and Neptune.

The very interesting opinion is entertained by some astronomers that there is at least one other great planet beyond Neptune. The orbits of certain comets are relied upon as furnishing evidence of the existence of such a body. Prof. George Forbes has estimated that this, as yet undiscovered, planet may be even greater than Jupiter in mass, and may be situated at a distance from the sun one hundred times as great as the earth’s, where it revolves in an orbit a single circuit of which requires a thousand years.

Whether this planet, with a year a thousand of our years in length, will ever be seen with a telescope, or whether its existence will ever, in some other manner, be fully demonstrated, can not yet be told. It will be remembered that Neptune was discovered by means of computations based upon its disturbing attraction on Uranus before it had ever been recognized with the telescope. But when the astronomers in the observatories were told by their mathematical brethren where to look they found the planet within half an hour after the search began. So it is possible the suspected great planet beyond Neptune may be within the range of telescopic vision, but may not be detected until elaborate calculations have deduced its place in the heavens. As a populous city is said to furnish the best hiding-place for a man who would escape the attention of his fellow beings, so the star-sprinkled sky is able to conceal among its multitudes worlds both great and small until the most painstaking detective methods bring them to recognition.

CHAPTER VIII

THE MOON, CHILD OF THE EARTH AND THE SUN

Very naturally the moon has always been a great favorite with those who, either in a scientific or in a literary spirit, have speculated about the plurality of inhabited worlds. The reasons for the preference accorded to the moon in this regard are evident. Unless a comet should brush us—as a comet is suspected of having done already—no celestial body, of any pretensions to size, can ever approach as near to the earth as the moon is, at least while the solar system continues to obey the organic laws that now control it. It is only a step from the earth to the moon. What are 240,000 miles in comparison with the distances of the stars, or even with the distances of the planets? Jupiter, driving between the earth and the moon, would occupy more than one third of the intervening space with the chariot of his mighty globe; Saturn, with broad wings outspread, would span more than two thirds of the distance; and the sun, so far from being able to get through at all, would overlap the way more than 300,000 miles on each side.

In consequence, of course, of its nearness, the moon is the only member of the planetary system whose principal features are visible to the naked eye. In truth, the naked eye perceives the larger configurations of the lunar surface more clearly than the most powerful telescope shows the details on the disk of Mars. Long before the time of Galileo and the invention of the telescope, men had noticed that the face of the moon bears a resemblance to the appearance that the earth would present if viewed from afar off. In remote antiquity there were philosophers who thought that the moon was an inhabited world, and very early the romancers took up the theme. Lucian, the Voltaire of the second century of our era, mercilessly scourged the pretenders of the earth from an imaginary point of vantage on the moon, which enabled him to peer down into their secrets. Lucian's description of the appearance of the earth from the moon shows how clearly defined in his day had become the conception of our globe as only an atom in space.

"Especially did it occur to me to laugh at the men who were quarreling about the boundaries of their land, and at those who were proud because they cultivated the Sikyonian plain, or owned that part of Marathon around Œnoe, or held possession of a thousand acres at Acharnæ. Of the whole of Greece, as it then appeared to me from above, being about the size of four fingers, I think Attica was in proportion a mere speck. So that I wondered on what condition it was left to these rich men to be proud."[14]

Such scenes as Lucian beheld, in imagination, upon the earth while looking from the moon, many would fain behold, with telescopic aid, upon the moon while looking from the earth. Galileo believed that the details of the lunar surface revealed by his telescope closely resembled in their nature the features of the earth's surface, and for a long time, as the telescope continued to be improved, observers were impressed with the belief that the moon possessed not only mountains and plains, but seas and oceans also.

It was the discovery that the moon has no perceptible atmosphere that first seriously undermined the theory of its habitability. Yet, as was remarked in the introductory chapter, there has of late been some change of view concerning a lunar atmosphere; but the change has been not so much in the ascertained facts as in the way of looking at those facts.

But before we discuss this matter, it will be well to state what is known beyond peradventure about the moon.

Its mean distance from the earth is usually called, for the sake of a round number, 240,000 miles, but more accurately stated it is 238,840 miles. This is variable to the extent of more than 31,000 miles, on account of the eccentricity of its orbit, and the eccentricity itself is variable, in consequence of the perturbing attractions of the earth and the sun, so that the distance of the moon from the earth is continually changing. It may be as far away as 253,000 miles and as near as 221,600 miles.

Although the orbit of the moon is generally represented, for convenience, as an ellipse about the earth, it is, in reality, a varying curve, having the sun for its real focus, and always concave toward the latter. This is a fact that can be more readily explained with the aid of a diagram.

The Moon's Path with Respect to the Sun and the Earth.

The Moon's Path with Respect to the Sun and the Earth.

In the accompanying cut, when the earth is at *A* the moon is between it and the sun, in the phase called new moon. At this point the earth's orbit about the sun is more curved than the moon's, and the earth is moving relatively faster than the moon, so that when it arrives at *B* it is ahead of the moon, and we see the latter to the right of the earth, in the phase called first quarter. The earth being at this time ahead of the moon, the effect of its attraction, combined with that of the sun, tends to hasten the moon onward in its orbit about the sun, and the moon begins to travel more swiftly, until it overtakes the earth at *C*, and appears on the side opposite the sun, in the phase called full moon. At this point the moon's orbit about the sun has a shorter radius of curvature than the earth's. In traveling from *C* to *D* the moon still moves more rapidly than the earth, and, having passed it, appears at *D* to the left of the earth, in the phase called third quarter. Now, the earth being behind the moon, the effect of its attraction combined with the sun's tends to retard the moon in its orbit about the sun, with the result that the moon moves again less rapidly than the earth, and the latter overtakes it, so that, upon reaching *E*, the two are once more in the same relative positions that they occupied at *A*, and it is again new moon. Thus it will be seen that, although the real orbit of the moon has the sun for its center of revolution, nevertheless, in consequence of the attraction of the earth, combined in varying directions with that of the sun, the moon, once every month, makes a complete circuit of our globe.

The above explanation should not be taken for a mathematical demonstration of the moon's motion, but simply for a graphical illustration of how the moon appears to revolve about the earth while really obeying the sun's attraction as completely as the earth does.

There is no other planet that has a moon relatively as large as ours. The moon's diameter is 2,163 miles. Its volume, compared with the earth's, is in the ratio of 1 to 49, and its density is about six tenths of the earth's. This makes its mass to that of our globe about as 1 to 81. In other words, it would take eighty-one moons to counterbalance the earth. Before speaking of the force of gravity on the moon we will examine the character of the lunar surface.

To the naked eye the moon's face appears variegated with dusky patches, while a few points of superior brilliance shine amid the brighter portions, especially in the southern and eastern quarters, where immense craters like Tycho and Copernicus are visible to a keen eye, gleaming like polished buttons. With a telescope, even of moderate power, the surface of the moon presents a scene of astonishing complexity, in which strangeness, beauty, and grandeur are all combined. The half of the moon turned earthward contains an area of 7,300,000 square miles, a little greater than the area of South America and a little less than that of North America. Of these 7,300,000 square miles, about 2,900,000 square miles are occupied by the gray, or dusky, expanses, called in lunar geography, or selenography, *maria*—i.e., "seas." Whatever they may once have been, they are not now seas, but dry plains, bordered in many places by precipitous cliffs and mountains, varied in level by low ridges and regions of depression, intersected occasionally by immense cracks, having the width and depth of our mightiest river cañons, and sprinkled with bright points and crater pits. The remaining 4,400,000 square miles are mainly occupied by mountains of the most extraordinary character. Owing partly to roughness of the surface and partly to more brilliant reflective power, the mountainous regions of the moon appear bright in comparison with the dull-colored plains.

Some of the lunar mountains lie in long, massive chains, with towering peaks, profound gorges, narrow valleys, vast amphitheaters, and beetling precipices. Looking at them with a powerful telescope, the observer might well fancy himself to be gazing down from an immense height into the heart of the untraveled Himalayas. But these, imposing though they are, do not constitute the most wonderful feature of the mountain scenery of the moon.

Appearing sometimes on the shores of the "seas," sometimes in the midst of broad plains, sometimes along the course of mountain chains, and sometimes in magnificent rows, following for hundreds of miles the meridians of the lunar globe, are tremendous, mountain-walled, circular chasms, called craters. Frequently they have in the middle of their depressed interior floors a peak, or a cluster of peaks. Their inner and outer walls are seamed with ridges, and what look like gigantic streams of frozen lava surround them. The resemblance that they bear to the craters of volcanoes is, at first sight, so striking that probably nobody would ever have thought of questioning the truth of the statement that they are such craters but for their incredible magnitude. Many of them exceed fifty miles in diameter, and some of them sink two, three, four, and more miles below the loftiest points upon their walls! There is a chasm, 140 miles long and 70 broad, named Newton, situated about 200 miles from the south pole of the moon, whose floor lies 24,000 feet below the summit of a peak that towers just above it on the east! This abyss is so profound that the shadows of its enclosing precipices never entirely quit it, and the larger part of its bottom is buried in endless night.

One can not but shudder at the thought of standing on the broken walls of Newton, and gazing down into a cavity of such stupendous depth that if Chimborazo were thrown into it, the head of the mighty Andean peak would be thousands of feet beneath the observer.

A different example of the crater mountains of the moon is the celebrated Tycho, situated in latitude about 43° south, corresponding with the latitude of southern New Zealand on the earth. Tycho is nearly circular and a little more than 54 miles across. The highest point on its wall is about 17,000 feet above the interior. In the middle of its floor is a mountain 5,000 or 6,000 feet high. Tycho is especially remarkable for the vast system of whitish streaks, or rays, which starting from its outer walls, spread in all directions over the face of the moon, many of them, running, without deviation, hundreds of miles across mountains, craters, and plains. These rays are among the greatest of lunar mysteries, and we shall have more to say of them.

THE LUNAR ALPS, APENNINES, AND CAUCASUS. Photographed with the Lick Telescope.

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Copernicus, a crater mountain situated about 10° north of the equator, in the eastern hemisphere of the moon, is another wonderful object, 56 miles in diameter, a polygon appearing, when not intently studied, as a circle, 11,000 or 12,000 feet deep, and having a group of relatively low peaks in the center of its floor. Around Copernicus an extensive area of the moon’s surface is whitened with something resembling the rays of Tycho, but more irregular in appearance. Copernicus lies within the edge of the great plain named the *Oceanus Procellarum*, or “Ocean of Storms,” and farther east, in the midst of the “ocean,” is a smaller crater mountain, named Kepler, which is also enveloped by a whitish area, covering the lunar surface as if it were the result of extensive outflows of light-colored lava.

In one important particular the crater mountains of the moon differ from terrestrial volcanoes. This difference is clearly described by Nasmyth and Carpenter in their book on The Moon:

“While the terrestrial crater is generally a hollow on a mountain top, with its flat bottom high above the level of the surrounding country, those upon the moon have their lowest points depressed more or less deeply below the general surface of the moon, the external height being frequently only a half or one third of the internal depth.”

It has been suggested that these gigantic rings are only “basal wrecks” of volcanic mountains, whose conical summits have been blown away, leaving vast crateriform hollows where the mighty peaks once stood; but the better opinion seems to be that which assumes that the rings were formed by volcanic action very much as we now see them. If such a crater as Copernicus or the still larger one named Theophilus, which is situated in the western hemisphere of the moon, on the shore of the “Sea of Nectar,” ever had a conical mountain rising from its rim, the height attained by the peak, if the average slope were about 30°, would have been truly stupendous—fifteen or eighteen miles!

There is a kind of ring mountains, found in many places on the moon, whose forms and surroundings do not, as the craters heretofore described do, suggest at first sight a volcanic origin. These are rather level plains of an oval or circular outline, enclosed by a wall of mountains. The finest example is, perhaps, the dark-gray Plato, situated in 50° of north latitude, near an immense mountain uplift named the Lunar Alps, and on the northern shore of the *Mare Imbrium*, or “Sea of Showers.” Plato appears as an oval plain, very smooth and level, about 60 miles in length, and completely surrounded by mountains, quite precipitous on the inner side, and rising in their highest peaks to an elevation of 6,000 to 7,000 feet. Enclosed plains, bearing more or less resemblance to Plato—sometimes smooth within, and sometimes broken with small peaks and craters or hilly ridges—are to be found scattered over almost all parts of the moon. If our satellite was ever an inhabited world like the earth, while its surface was in its present condition, these valleys must have presented an extraordinary spectacle. It has been thought that they may once have been filled with water, forming lakes that recall the curious Crater Lake of Oregon.

THE MOON AT FIRST AND LAST QUARTER (WESTERN AND EASTERN HEMISPHERES). Photographed with the Lick Telescope.

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It is not my intention to give a complete description of the various lunar features, and I mention but one other—the "clefts" or "rills," which are to be seen running across the surface like cracks. One of the most remarkable of these is found in the *Oceanus Procellarum*, near the crater-mountain Aristarchus, which is famed for the intense brilliance of its central peak, whose reflective power is so great that it was once supposed to be aflame with volcanic fire. The cleft, or crack, in question is very erratic in its course, and many miles in length, and it terminates in a ringed plain named Herodotus not far east of Aristarchus, breaking through the wall of the plain and entering the interior. Many other similar chasms or cañons exist on the moon, some crossing plains, some cleaving mountain walls, and some forming a network of intersecting clefts. Mr. Thomas Gwyn Elger has this to say on the subject of the lunar clefts:

"If, as seems most probable, these gigantic cracks are due to contractions of the moon's surface, it is not impossible, in spite of the assertions of the text-books to the effect that our satellite is now a 'changeless world,' that emanations may proceed from these fissures, even if, under the monthly alternations of extreme temperatures, surface changes do not now occasionally take place from this cause also. Should this be so, the appearance of new rills and the extension and modification of those already existing may reasonably be looked for."

Mr. Elger then proceeds to describe his discovery in 1883, in the ring-plain Mersenius, of a cleft never noticed before, and which seems to have been of recent formation.[15]

We now return to the question of the force of lunar gravity. This we find to be only one sixth as great as gravity on the surface of the earth. It is by far the smallest force of gravity that we have found anywhere except on the asteroids. Employing the same method of comparison that was made in the case of Mars, we compute that a man on the moon could attain a height of thirty-six feet without being relatively more unwieldy than a six-foot descendant of Adam is on the earth.

Whether this furnishes a sound reason for assuming that the lunar inhabitants, if any exist or have ever existed, should be preposterous giants is questionable; yet such an assumption receives a certain degree of support from the observed fact that the natural features of the moon are framed on an exaggerated scale as compared with the earth's. We have just observed that the moon is characterized by vast mountain rings, attaining in many cases a diameter exceeding fifty miles. If these are volcanic craters, it is evident, at a glance, that the mightiest volcanoes of the earth fall into insignificance beside them. Now, the slight force of gravity on the moon has been appealed to as a reason why volcanic explosions on the lunar globe should produce incomparably greater effects than upon the earth, where the ejected materials are so much heavier. The same force that would throw a volcanic bomb a mile high on the earth could throw it six miles high on the moon. The giant cannon that we have placed in one of our coast forts, which is said to be able to hurl a projectile to a distance of fifteen miles, could send the same projectile ninety miles on the moon. An athlete who can clear a horizontal bar at a height of six feet on the earth could clear the same bar at a height of thirty-six feet on the moon. In other words, he could jump over a house, unless, indeed, the lunarians really are giants, and live in houses proportioned to their own dimensions and to the size of their mountains. In that case, our athlete would have to content himself with jumping over a lunarian, whose head he could just clear—with the hat off.

These things are not only amusing, but important. There can be no question that the force of gravity on the moon actually is as slight as it has just been described. So, even without calling in imaginary inhabitants to lend it interest, the comparative inability of the moon to arrest bodies in motion becomes a fact of much significance. It has led to the theory that meteorites may have originally been shot out of the moon's great volcanoes, when those volcanoes were active, and may have circulated about the sun until various perturbations have brought them down upon the earth. A body shot radially from the surface of the moon would need to have a velocity of only about a mile and a half in a second in order to escape from the moon's control, and we can believe that a lunar volcano when in action could have imparted such a velocity, all the more readily because with modern gunpowders we have been able to give to projectiles a speed one half as great as that needed for liberation from lunar gravity.

Another consequence of the small gravitative power of the moon bears upon the all-important question of atmosphere. According to the theory of Dr. Johnstone Stoney, heretofore referred to, oxygen, nitrogen, and water vapor would all gradually escape from the moon, if originally placed upon it, because, by the kinetic theory, the maximum velocities of their molecules are greater than a mile and a half per second. The escape would not occur instantly, nor all at once, for it would be only the molecules at the upper surface of the atmosphere which were moving with their greatest velocity, and in a direction radial to the center of the moon, that would get away; but in the course of time this gradual leakage would result in the escape of all of those gases.[16]

After it had been found that, to ordinary tests, the moon offered no evidence of the possession of an atmosphere, and before Dr. Stoney's theory was broached, it was supposed by many that the moon had lost its original supply of air by absorption into its interior. The oxygen was supposed to have entered into combination with the cooling rocks and minerals, thus being withdrawn from the atmosphere, and the nitrogen was imagined to have disappeared also within the lunar crust. For it seems to have always been tacitly assumed that the phenomenon to be accounted for was not so much the *absence* of a lunar atmosphere as its *disappearance*. But disappearance, of course, implies previous existence. In like manner it has always been a commonly accepted view that the moon probably once had enough water to form lakes and seas.

These, it has been calculated, could have been absorbed into the lunar globe as it cooled off. But Johnstone Stoney's theory offers another method by which they could have escaped, through evaporation and the gradual flight of the molecules into open space. Possibly both methods have been in operation, a portion of the constituents of the former atmosphere and oceans having entered into chemical combinations in the lunar crust, and the remainder having vanished in consequence of the lack of sufficient gravitative force to retain them.

But why, it may be asked, should it be assumed that the moon ever had things which it does not now possess? Perhaps no entirely satisfactory reply can be made. Some observers have believed that they detected unmistakable indications of alluvial deposits on lunar plains, and of the existence of beaches on the shores of the "seas." Messrs. Loewy and Puiseux, of the Paris Observatory, whose photographs of the moon are perhaps the finest yet made, say on this subject:

"There exists, from the point of view of relief, a general similarity between the 'seas' of the moon and the plateaux which are covered to-day by terrestrial oceans. In these convex surfaces are more frequent than concave basins, thrown back usually toward the verge of the depressed space. In the same way the 'seas' of the moon present, generally at the edges, rather pronounced depressions. In one case, as in the other, we observe normal deformations of a shrinking globe shielded from the erosive action of rain, which tends, on the contrary, in all the abundantly watered parts of the earth to make the concave surfaces predominate. The explanation of this structure, such as is admitted at present by geologists, seems to us equally valid for the moon."[17]

It might be urged that there is evidence of former volcanic activity on the moon of such a nature that explosions of steam must have played a part in the phenomena, and if there was steam, of course there was water.

But perhaps the most convincing argument tending to show that the moon once had a supply of water, of which some remnant may yet remain below the surface of the lunar globe, is based upon the probable similarity in composition of the earth and the moon. This similarity results almost equally whether we regard the moon as having originated in a ring of matter left off from the contracting mass that became the earth, or whether we accept the suggestion of Prof. G.H. Darwin, that the moon is the veritable offspring of the earth, brought into being by the assistance of the tidal influence of the sun. The latter hypothesis is the more picturesque of the two, and, at present, is probably the more generally favored. It depends upon the theory of tidal friction, which was referred to in Chapter III, as offering an explanation of the manner in which the rotation of the planet Mercury has been slowed down until its rotary period coincides with that of its revolution.

The gist of the hypothesis in question is that at a very early period in its history, when the earth was probably yet in a fluid condition, it rotated with extreme rapidity on its axis, and was, at the same time, greatly agitated by the tidal attraction of the sun, and finally huge masses were detached from the earth which, ultimately uniting, became the moon.[18]

Born in this manner from the very substance of the earth, the moon would necessarily be composed, in the main, of the same elements as the globe on which we dwell, and is it conceivable that it should not have carried with it both air and water, or the gases from which they were to be formed? If the moon ever had enough of these prime requisites to enable it to support forms of life comparable with those of the earth, the disappearance of that life must have been a direct consequence of the gradual vanishing of the lunar air and water. The secular drying up of the oceans and wasting away of the atmosphere on our little neighbor world involved a vast, all-embracing tragedy, some of the earlier scenes of which, if theories be correct, are now reenacted on the half-desiccated planet Mars—a planet, by the way, which in size, mass, and ability to retain vital gases stands about half-way between the earth and the moon.

One of the most interesting facts about the moon is that its surface affords evidence of a cataclysm which has wiped out many, and perhaps nearly all, of the records of its earlier history, that were once written upon its face. Even on the earth there have been geological catastrophes destroying or burying the accumulated results of ages of undisturbed progress, but on the moon these effects have been transcendent. The story of the tremendous disaster that overtook the moon is partly written in its giant volcanoes. Although it may be true, as some maintain, that there is yet volcanic action going on upon the lunar surface, it is evident that such action must be insignificant in comparison with that which took place ages ago.

There is a spot in the western hemisphere of the moon, on the border of a placid bay or "sea," that I can never look at without a feeling of awe and almost of shrinking. There, within a space about 250 miles in length by 100 in width, is an exhibition of the most terrifying effects of volcanic energy that the eye of man can anywhere behold. Three immense craters—Theophilus, 64 miles across and 3-1/2 miles deep; Cyrillus, 60 miles across and 15,000 feet deep; and Catharina, 70 miles across and from 8,000 to 16,000 feet deep—form an interlinked chain of mountain rings, ridges, precipices, chasms, and bottomless pits that take away one's breath.

But when the first impression of astonishment and dismay produced by this overwhelming spectacle has somewhat abated, the thoughtful observer will note that here the moon is telling him a part of her wonderful story, depicted in characters so plain that he needs no instruction in order to decipher their meaning. He will observe that this ruin was not all wrought at once or simultaneously. Theophilus, the crater-mountain at the northwestern end of the chain, whose bottom lies deepest of all, is the youngest of these giants, though the most imposing. For a distance of forty miles the lofty wall of Theophilus has piled itself upon the ruins of the wall of Cyrillus, and the circumference of the circle of its tremendous crater has been forcibly thrust within the original rim of the more ancient crater, which was thus rudely compelled to make room for its more vigorous rival and successor.

The observer will also notice that Catharina, the huge pit at the southeastern end of the chain, bears evidence of yet greater age. Its original walls, fragments of which still stand in broken grandeur, towering to a height of 16,000 feet, have, throughout the greater part of their circuit, been riddled by the outbreak of smaller craters, and torn asunder and thrown down on all sides.

In the vast enclosure that was originally the floor of the crater-mountain Catharina, several crater rings, only a third, a quarter, or a fifth as great in diameter, have broken forth, and these in turn have been partially destroyed, while in the interior of the oldest of them yet smaller craters, a nest of them, mere Etnas, Cotopaxis, and Kilaueas in magnitude, simple pinheads on the moon, have opened their tiny jaws in weak and ineffective expression of the waning energies of a still later epoch, which followed the truly heroic age of lunar vulcanicity.

This is only one example among hundreds, scattered all over the moon, which show how the surface of our satellite has suffered upheaval after upheaval. It is possible that some of the small craters, not included within the walls of the greater ones, may represent an early stage in the era of volcanic activity that wrecked the moon, but where larger and smaller are grouped together a certain progression can be seen, tending finally to extinction. The internal energies reached a maximum and then fell off in strength until they died out completely.

It can hardly be supposed that the life-bearing phase of lunar history—if there ever was one—could survive the outbreak of the volcanic cataclysm. North America, or Europe, if subjected to such an experience as the continental areas of the moon have passed through, would be, in proportion, worse wrecked than the most fearfully battered steel victim of a modern sea fight, and one can readily understand that, in such circumstances, those now beautiful and populous continents would exhibit, from a distance, scarcely any token of their present topographical features, to say nothing of any relics of their occupation by living creatures.

There are other interesting glimpses to be had of an older world in the moon than that whose scarred face is now beautified for us by distance. Not far from Theophilus and the other great crater-mountains just described, at the upper, or southern, end of the level expanse called the "Sea of Nectar," is a broad, semicircular bay whose shores are formed by the walls of a partially destroyed crater named Fracastorius. It is evident that this bay, and the larger part of the "Sea of Nectar," have been created by an outwelling of liquid lavas, which formed a smooth floor over a portion of the pre-existing surface of the moon, and broke down and submerged a large part of the mountain ring of Fracastorius, leaving the more ancient walls standing at the southern end, while, outlined by depressions and corrugations in the rocky blanket, are certain half-defined forms belonging to the buried world beneath.

Near Copernicus, some years ago, as Dr. Edward S. Holden pointed out, photographs made with the great Lick telescope, then under his direction, showed, in skeleton outline, a huge ring buried beneath some vast outflow of molten matter and undiscerned by telescopic observers. And Mr. Elger, who was a most industrious observer and careful interpreter of lunar scenery, speaks of "the undoubted existence of the relics of an earlier lunar world beneath the smooth superficies of the *maria*."

Although, as already remarked, it seems necessary to assume that any life existing in the moon prior to its great volcanic outburst must have ceased at that time, yet the possibility may be admitted that life could reappear upon the moon after its surface had again become quiet and comparatively undisturbed. Germs of the earlier life might have survived, despite the terrible nature of the catastrophe. But the conditions on the moon at present are such that even the most confident advocates of the view that the lunar world is not entirely dead do not venture to assume that anything beyond the lowest and simplest organic forms—mainly, if not wholly, in the shape of vegetation—can exist there. The impression that even such life is possible rests upon the accumulating evidence of the existence of a lunar atmosphere, and of visible changes, some apparently of a volcanic character and some not, on the moon’s surface.

Prof. William H. Pickering, who is, perhaps, more familiar with the telescopic and photographic aspects of the moon than any other American astronomer, has recorded numberless instances of change in minute details of the lunar landscapes. He regards some of his observations made at Arequipa as “pointing very strongly to the existence of vegetation upon the surface of the moon in large quantities at the present time.” The mountain-ringed valley of Plato is one of the places in the lunar world where the visible changes have been most frequently observed, and more than one student of the moon has reached the conclusion that something very like the appearances that vegetation would produce is to be seen in that valley.

Professor Pickering has thoroughly discussed the observations relating to a celebrated crater named Linné in the *Mare Serenitatis*, and after reading his description of its changes of appearance one can hardly reject his conclusion that Linné is an active volcanic vent, but variable in its manifestations. This is only one of a number of similar instances among the smaller craters of the moon. The giant ones are evidently entirely extinct, but some of the minor vents give occasional signs of activity. Nor should it be assumed that these relatively slight manifestations of volcanic action are really insignificant. As Professor Pickering shows, they may be regarded as comparable with the greatest volcanic phenomena now witnessed on the earth, and, speaking again of Plato, he says of its evidences of volcanic action:

“It is, I believe, more active than any area of similar size upon the earth. There seems to be no evidences of lava, but the white streaks indicate apparently something analogous to snow or clouds. There must be a certain escape of gases, presumably steam and carbonic acid, the former of which, probably, aids in the production of the white markings.”[19]

To Professor Pickering we owe the suggestion that the wonderful rays emanating from Tycho consist of some whitish substance blown by the wind, not from Tycho itself, but from lines of little volcanic vents or craters lying along the course of the rays. This substance may be volcanic powder or snow, in the form of minute ice crystals. Mr. Elger remarks of this theory that the “confused network of streaks” around Copernicus seems to respond to it more happily than the rays of Tycho do, because of the lack of definiteness of direction so manifest in the case of the rays.

As an encouragement to amateur observers who may be disposed to find out for themselves whether or not changes now take place in the moon, the following sentence from the introduction to Professor Pickering’s chapter on Plato in the Harvard Observatory Annals, volume xxxii, will prove useful and interesting:

“In reviewing the history of selenography, one must be impressed by the singular fact that, while most of the astronomers who have made a special study of the moon, such as Schroeter, Maedler, Schmidt, Webb, Neison, and Elger, have all believed that its surface was still subject to changes readily visible from the earth, the great majority of astronomers who have paid little attention to the subject have quite as strenuously denied the existence of such changes.”

In regard to the lunar atmosphere, it may be said, in a word, that even those who advocate the existence of vegetation and of clouds of dust or ice crystals on the moon do not predicate any greater amount, or greater density, of atmosphere than do those who consider the moon to be wholly dead and inert. Professor Pickering himself showed, from his observations, that the horizontal refraction of the lunar atmosphere, instead of being less than 2″, as formerly stated, was less than 0.4″. Yet he found visual evidence that on the sunlit side of the moon this rare atmosphere was filled to a height of four miles with some absorbing medium which was absent on the dark side, and which was apparently an emanation from the lunar crust, occurring after sunrise. And Messrs. Loewy and Puiseux, of the Paris Observatory, say, after showing reasons for thinking that the great volcanic eruptions belong to a recent period in the history of the moon, that "the diffusion of cinders to great distances infers a gaseous envelope of a certain density…. The resistance of the atmosphere must have been sufficient to retard the fall of this dust [the reference is to the white trails, like those from Tycho], during its transport over a distance of more than 1,000 kilometers [620 miles]."[20]

We come now to a brief consideration of certain peculiarities in the motions of the moon, and in the phenomena of day and night on its surface. The moon keeps the same side forever turned toward the earth, behaving, in this respect, as Mercury does with regard to the sun. The consequence is that the lunar globe makes but one rotation on its axis in the course of a month, or in the course of one revolution about the earth. Some of the results of this practical identity of the periods of rotation and revolution are illustrated in the diagram on page 250. The moon really undergoes considerable libration, recalling the libration of Mercury, which was explained in the chapter on that planet, and in consequence we are able to see a little way round into the opposite lunar hemisphere, now on this side and now on the other, but in the diagram this libration has been neglected. If it had been represented we should have found that, instead of only one half, about three fifths of the total superficies of the moon are visible from the earth at one time or another.

Phases and Rotation of the Moon.

PHASES AND ROTATION OF THE MOON.

Perhaps it should be remarked that in drawing the moon's orbit about the earth as a center we offer no contradiction to what was shown earlier in this chapter. The moon does travel around the earth, and its orbit about our globe may, for our present purpose, be treated independently of its motion about the sun. Let the central globe, then, represent the earth, and let the sun be supposed to shine from the left-hand side of the diagram. A little cross is erected at a fixed spot on the globe of the moon.

At *A* the moon is between the earth and the sun, or in the phase of new moon. The lunar hemisphere facing the earth is now buried in night, except so far as the light reflected from the earth illuminates it, and this illumination, it is interesting to remember, is about fourteen times as great—reckoned by the relative areas of the reflecting surfaces—as that which the full moon sends to the earth. An inhabitant of the moon, standing beside the cross, sees the earth in the form of a huge full moon directly above his head, but, as far as the sun is concerned, it is midnight for him.

In the course of about seven days the moon travels to *B*. In the meantime it has turned one quarter of the way around its axis, and the spot marked by the cross is still directly under the earth. For the lunar inhabitant standing on that spot the sun is now on the point of rising, and he sees the earth no longer in the shape of a full moon, but in that of a half-moon. The lunar globe itself appears, at the same time from the earth, as a half-moon, being in the position or phase that we call first quarter.

Seven more days elapse, and the moon arrives at *C*, opposite to the position of the sun, and with the earth between it and the solar orb. It is now high noon for our lunarian standing beside the cross, while the earth over his head appears, if he sees it at all, only as a black disk close to the sun, or—as would sometimes be the case—covering the sun, and encircled with a beautiful ring of light produced by the refraction of its atmosphere. (Recall the similar phenomenon in the case of Venus.) The moon seen from the earth is now in the phase called full moon.

Another lapse of seven days, and the moon is at *D*, in the phase called third quarter, while the earth, viewed from the cross on the moon, which is still pointed directly at it, appears again in the shape of a huge half-moon.

During the next seven days the moon returns to its original position at *A*, and becomes once more new moon, with “full earth” shining upon it.

Now it is evident that in consequence of the peculiar law of the moon’s rotation its days and nights are each about two of our weeks, or fourteen days, in length. That hemisphere of the moon which is in the full sunlight at *A*, for instance, is buried in the middle of night at *C*. The result is different than in the case of Mercury, because the body toward which the moon always keeps the same face directed is not the luminous sun, but the non-luminous earth.

It is believed that the moon acquired this manner of rotation in consequence of the tidal friction exercised upon it by the earth. The tidal attraction of the earth exceeds that of the sun upon the moon because the earth is so much nearer than the sun is, and tidal attraction varies inversely as the cube of the distance. In fact, the braking effect of tidal friction varies inversely as the sixth power of the distance, so that the ability of the earth to stop the rotation of the moon on its axis is immensely greater than that of the sun. This power was effectively applied while the moon was yet a molten mass, so that it is probable that the moon has rotated just as it does now for millions of years.

As was remarked a little while ago, the moon traveling in an elliptical orbit about the earth has a libratory movement which, if represented in our picture, would cause the cross to swing now a little one way and now a little the other, and thus produce an apparent pendulum motion of the earth in the sky, similar to that of the sun as seen from Mercury. But it is not necessary to go into the details of this phenomenon. The reader, if he chooses, can deduce them for himself.

But we may inquire a little into the effects of the long days and nights of the moon. In consequence of the extreme rarity of the lunar atmosphere, it is believed that the heat of the sun falling upon it during a day two weeks in length, is radiated away so rapidly that the surface of the lunar rocks never rises above the freezing temperature of water. On the night side, with no warm atmospheric blanket such as the earth enjoys, the temperature may fall far toward absolute zero, the most merciful figure that has been suggested for it being 200° below the zero of our ordinary thermometers! But there is much uncertainty about the actual temperature on the moon, and different experiments, in the attempt to make a direct measurement of it, have yielded discordant results. At one time, for instance, Lord Rosse believed he had demonstrated that at lunar noon the temperature of the rocks rose above the boiling-point of water. But afterward he changed his mind and favored the theory of a low temperature.

In this and in other respects much remains to be discovered concerning our interesting satellite, and there is plenty of room, and an abundance of original occupation, for new observers of the lunar world.

CHAPTER IX

HOW TO FIND THE PLANETS

There is no reason why everybody should not know the principal planets at sight nearly as well as everybody knows the moon. It only requires a little intelligent application to become acquainted with the other worlds that have been discussed in the foregoing chapters, and to be able to follow their courses through the sky and recognize them wherever they appear. No telescope, or any other instrument whatever, is required for the purpose. There is but one preliminary requirement, just as every branch of human knowledge presupposes its A B C. This is an acquaintance with the constellations and the principal stars—not a difficult thing to obtain.

Almost everybody knows the “Great Dipper” from childhood’s days, except, perhaps, those who have had the misfortune to spend their youth under the glare of city lights. Some know Orion when he shines gloriously in the winter heavens. Many are able to point out the north star, or pole star, as everybody should be able to do. All this forms a good beginning, and may serve as the basis for the rapid acquirement of a general knowledge of the geography of the heavens.

If you are fortunate enough to number an astronomer among your acquaintance—an amateur will do as well as a professor—you may, with his aid, make a short cut to a knowledge of the stars. Otherwise you must depend upon books and charts. My Astronomy with an Opera-Glass was prepared for this very purpose. For simply learning the constellations and the chief stars you need no opera-glass or other instrument. With the aid of the charts, familiarize yourself with the appearance of the constellations by noticing the characteristic arrangements of their chief stars. You need pay no attention to any except the bright stars, and those that are conspicuous enough to thrust themselves upon your attention.

Learn by observation at what seasons particular constellations are on, or near, the meridian—i.e., the north and south line through the middle of the heavens. Make yourself especially familiar with the so-called zodiacal constellations, which are, in their order, running around the heavens from west to east: Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, and Pisces. The importance of these particular constellations arises from the fact that it is across them that the tracks of the planets lie, and when you are familiar with the fixed stars belonging to them you will be able immediately to recognize a stranger appearing among them, and will correctly conclude that it is one of the planets.[21] How to tell which planet it may be, it is the object of this chapter to show you. As an indispensable aid—unless you happen already to possess a complete star atlas on a larger scale—I have drawn the six charts of the zodiacal constellations and their neighbors that are included in this chapter.

Chart No. 1.—From Right Ascension 0 Hours to 4 Hours; Declination 30° North to 10° South.

Chart No. 1.—From Right Ascension 0 Hours to 4 Hours; Declination 30° North to 10° South.

Having learned to recognize the constellations and their chief stars on sight, one other step, an extremely easy one, remains to be taken before beginning your search for the planets—buy the American Ephemeris and Nautical Almanac for the current year. It is published under the direction of the United States Naval Observatory at Washington, and can be purchased for one dollar.

This book, which may appear to you rather bulky and formidable for an almanac, contains hundreds of pages and scores of tables to which you need pay no attention. They are for navigators and astronomers, and are much more innocent than they look. The plain citizen, seeking only an introduction to the planets, can return their stare and pass by, without feeling in the least humiliated.

Chart No. 2.—From Right Ascension 4 Hours to 8 Hours; Declination 30° North to 10° South.

Chart No. 2.—From Right Ascension 4 Hours to 8 Hours; Declination 30° North to 10° South.

In the front part of the book, after the long calendar, and the tables relating to the sun and the moon, will be found about thirty pages of tables headed, in large black letters, with the names of the planets—Mercury, Venus, Mars, Jupiter, Saturn, etc. Two months are represented on each page, and opposite the number of each successive day of the month the position of the planet is given in hours, minutes, and seconds of right ascension, and degrees, minutes, and seconds of north and south declination, the sign + meaning north, and the sign − south. Do not trouble yourself with the seconds in either column, and take the minutes only when the number is large. The hours of right ascension and the degrees of declination are the main things to be noticed.

Right ascension, by the way, expresses the distance of a celestial body, such as a star or a planet, east of the vernal equinox, or the first point of Aries, which is an arbitrary point on the equator of the heavens, which serves, like the meridian of Greenwich on the earth, as a starting-place for reckoning longitude. The entire circuit of the heavens along the equator is divided into twenty-four hours of right ascension, each hour covering 15° of space. If a planet then is in right ascension (usually printed for short R.A.) 0 h. 0 m. 0 s., it is on the meridian of the vernal equinox, or the celestial Greenwich; if it is in R.A. 1 h., it will be found 15° east of the vernal equinox, and so on.

Chart No. 3.—From Right Ascension 8 Hours to 12 Hours; Declination 30° North to 10° South.

Chart No. 3.—From Right Ascension 8 Hours to 12 Hours; Declination 30° North to 10° South.

Declination (printed D. or Dec.) expresses the distance of a celestial body north or south of the equator of the heavens.

With these explanations we may proceed to find a planet by the aid of the Nautical Almanac and our charts. I take, for example, the ephemeris for the year 1901, and I look under the heading “Jupiter” on page 239, for the month of July. Opposite the 15th day of the month I find the right ascension to be 18 h. 27 m., neglecting the seconds. Now 27 minutes are so near to half an hour that, for our purposes, we may say Jupiter is in R.A. 18 h. 30 m. I set this down on a slip of paper, and then examine the declination column, where I find that on July 15 Jupiter is in south declination (the sign − meaning south, as before explained) 23° 17′ 52″, which is almost 23° 18′, and, for our purposes, we may call this 23° 20′, which is what I set down on my slip.

Chart No. 4.—From Right Ascension 12 Hours to 16 Hours; Declination 10° North to 30° South.

Chart No. 4.—From Right Ascension 12 Hours to 16 Hours; Declination 10° North to 30° South.

Next, I turn to Chart No. 5, in this chapter, where I find the meridian line of R.A. 18 h. running through the center of the chart. I know that Jupiter is to be looked for about 30 m. east, or to the left, of that line. At the bottom and top of the chart, every twenty minutes of R.A. is indicated, so that it is easy, with the eye, or with the aid of a ruler, to place the vertical line at some point of which Jupiter is to be found.

Chart No. 5.—From Right Ascension 16 Hours to 20 Hours; Declination 10° North to 30° South.

Chart No. 5.—From Right Ascension 16 Hours to 20 Hours; Declination 10° North to 30° South.

Then I consult my note of the declination of the planet. It is south 23° 20′. On the vertical borders of the chart I find the figures of the declination, and I observe that 0° Dec., which represents the equator of the heavens, is near the top of the chart, while each parallel horizontal line across the chart indicates 10° north or south of its next neighbor. Next to the bottom of the chart I find the parallel of 20°, and I see that every five degrees is indicated by the figures at the sides. By the eye, or with the aid of a ruler, I easily estimate where the horizontal line of 23° would fall, and since 20′ is the third of a degree I perceive that it is, for the rough purpose of merely finding a conspicuous planet, negligible, although it, too, can be included in the estimate, if thought desirable.

Having already found the vertical line on which Jupiter is placed and having now found the horizontal line also, I have simply to regard their crossing point, which will be the situation of the planet among the stars. I note that it is in the constellation Sagittarius in a certain position with reference to a familiar group of stars in that constellation, and when I look at the heavens, there, in the place thus indicated, Jupiter stands revealed.

Chart No. 6.—From Right Ascension 20 Hours to 24 Hours (0 II.); Declination 10° North to 30° South.

Chart No. 6.—From Right Ascension 20 Hours to 24 Hours (0 II.); Declination 10° North to 30° South.

The reader will readily perceive that, in a precisely similar manner, any planet can be located, at any time of the year, and at any point in its course about the heavens. But it may turn out that the place occupied by the planet is too near the sun to render it easily, or at all, visible. Such a case can be recognized, either from a general knowledge of the location of the constellations at various seasons, or with the aid of the Nautical Almanac, where at the beginning of each set of monthly tables in the calendar the sun’s right ascension and declination will be found. In locating the sun, if you find that its right ascension differs by less than an hour, one way or the other, from that of the planet sought, it is useless to look for the latter. If the planet is situated west of the sun—to the right on the chart—then it is to be looked for in the east before sunrise. But if it is east of the sun—to the left on the chart—then you must seek it in the west after sunset.

For instance, I look for the planet Mercury on October 12, 1901. I find its R.A. to be 14 h. 40 m. and its Dec. 18° 36′. Looking at the sun's place for October 12th, I find it to be R.A. 13 h. 8 m. and Dec. 7° 14′. Placing them both on Chart No. 4, I discover that Mercury is well to the east, or left hand of the sun, and will consequently be visible in the western sky after sundown.

Additional guidance will be found by noting the following facts about the charts:

The meridian (the north and south line) runs through the middle of Chart No. 1 between 11 and 12 o'clock P.M. on November 1st, between 9 and 10 o'clock P.M. on December 1st, and between 7 and 8 o'clock P.M. on January 1st.

The meridian runs through the middle of Chart No. 2 between 11 and 12 o'clock P.M. on January 1st, between 9 and 10 o'clock P.M. on February 1st, and between 7 and 8 o'clock P.M. on March 1st.

The meridian runs through the middle of Chart No. 3 between 11 and 12 o'clock P.M. on March 1st, between 9 and 10 o'clock P.M. on April 1st, and between 7 and 8 o'clock P.M. on May 1st.

The meridian runs through the middle of Chart No. 4 between 11 and 12 o'clock P.M. on May 1st, between 9 and 10 o'clock P.M. on June 1st, and between 7 and 8 o'clock P.M. on July 1st.

The meridian runs through the middle of Chart No. 5 between 11 and 12 o'clock P.M. on July 1st, between 9 and 10 o'clock P.M. on August 1st, and between 7 and 8 o'clock P.M. on September 1st.

The meridian runs through the middle of Chart No. 6 between 11 and 12 o'clock P.M. on September 1st, between 9 and 10 o'clock P.M. on October 1st, and between 7 and 8 o'clock P.M. on November 1st.

Note well, also, these particulars about the charts: Chart No. 1 includes the first four hours of right ascension, from 0 h. to 4 h. inclusive; Chart No. 2 includes 4 h. to 8 h.; Chart No. 3, 8 h. to 12 h.; Chart No. 4, 12 h. to 16 h.; Chart No. 5, 16 h. to 20 h.; and Chart No. 6, 20 h. to 24 h., which completes the circuit. In the first three charts the line of 0°, or the equator, is found near the bottom, and in the last three near the top. This is a matter of convenience in arrangement, based upon the fact that the ecliptic, which, and not the equator, marks the center of the zodiac, indicates the position of the tracks of the planets among the stars; and the ecliptic, being inclined 23° to the plane of the equator, lies half to the north and half to the south of the latter.

Those who, after all, may not care to consult the ephemeris in order to find the planets, may be able to locate them, simply from a knowledge of their situation among the constellations. Some ordinary almanacs tell in what constellations the principal planets are to be found at various times of the year. Having once found them in this way, it is comparatively easy to keep track of them thereafter through a general knowledge of their movements. Jupiter, for instance, requiring a period of nearly twelve years to make a single journey around the sun, moves about 30° eastward among the stars every year. The zodiacal constellations are roughly about 30° in length, and as Jupiter was in Sagittarius in 1901, he will be in Capricornus in 1902. Saturn, requiring nearly thirty years for a revolution around the sun, moves only between 12° and 13° eastward every year, and, being in conjunction with Jupiter in Sagittarius in 1901, does not get beyond the border of that constellation in 1902.

Jupiter having been in opposition to the sun June 30, 1901, will be similarly placed early in August, 1902, the time from one opposition of Jupiter to the next being 399 days.

Saturn passes from one opposition to the next in 378 days, so that having been in that position July 5, 1901, it reaches it again about July 18, 1902.

Mars requires about 687 days to complete a revolution, and comes into conjunction with the earth, or opposition to the sun—the best position for observation—on the average once every 780 days. Mars was in opposition near the end of February, 1901, and some of its future oppositions will be in March, 1903; May, 1905; July, 1907; and September, 1909. The oppositions of 1907 and 1909 will be unusually favorable ones, for they will occur when the planet is comparatively near the earth. When a planet is in opposition to the sun it is on the meridian, the north and south line, at midnight.

Mercury and Venus being nearer the sun than the earth is, can never be seen very far from the place of the sun itself. Venus recedes much farther from the solar orb than Mercury does, but both are visible only in the sunset or the sunrise sky. All almanacs tell at what times these planets play their respective rôles as morning or as evening stars. In the case of Mercury about 116 days on the average elapse between its reappearances; in the case of Venus, about 584 days. The latter, for instance, having become an evening star at the end of April, 1901, will become an evening star again in December, 1902.

With the aid of the Nautical Almanac and the charts the amateur will find no difficulty, after a little practise, in keeping track of any of the planets.

In the back part of the Nautical Almanac will be found two pages headed “Phenomena: Planetary Configurations.” With the aid of these the student can determine the position of the planets with respect to the sun and the moon, and with respect to one another. The meaning of the various symbols used in the tables will be found explained on a page facing the calendar at the beginning of the book. From these tables, among other things, the times of greatest elongation from the sun of the planets Mercury and Venus can be found.

It may be added that only bright stars, and stars easily seen, are included in the charts, and there will be no danger of mistaking any of these stars for a planet, if the observer first carefully learns to recognize their configurations. Neither Mars, Jupiter, nor Saturn ever appears as faint as any of the stars, except those of the first magnitude, included in the charts. Uranus and Neptune being invisible to the naked eye—Uranus can occasionally be just glimpsed by a keen eye—are too faint to be found without the aid of more effective appliances.

FOOTNOTES:

[1] L’Astronomie, vol. i, 1882, pp. 217 *et seq.*

[2] The reader can find many of these “canals” and “oases,” as well as some of the other regions on Mars that have received names, in the frontispiece.

[3] Mars, by Percival Lowell, p. 207 *et seq.*

[4] General Astronomy, by Charles A. Young. Revised edition, 1898, p. 363.

[5] Many of the present difficulties about temperatures on the various planets would be beautifully disposed of if we could accept the theory urged by Mr. Cope Whitehouse, to the effect that the sun is not really a hot body at all, and that what we call solar light and heat are only local manifestations produced in our atmosphere by the transformation of some other form of energy transmitted from the sun; very much as the electric impulses carried by a wire from the transmitting to the receiving station on a telephone line are translated by the receiver into waves of sound. According to this theory, which is here mentioned only as an ingenuity and because something of the kind so frequently turns up in one form or another in popular semi-scientific literature, the amount of heat and light on a planet would depend mainly upon local causes.

[6] Grant's History of Physical Astronomy, p. 241.

[7] Popular Astronomy, by Simon Newcomb, p. 335.

[8] General Astronomy, by Charles A. Young. Revised edition, 1898, p. 372.

[9] "Since the discovery of Eros, the extraordinary position of its orbit has led to the suggestion that possibly Mars itself, instead of being regarded as primarily a major planet, belonging to the terrestrial group, ought rather to be considered as the greatest of the asteroids, and a part of the original body from which the asteroidal system was formed."—J. Bauschinger, Astronomische Nachrichten, No. 3542.

[10] The Observatory, No. 286, December, 1899.

[11] Davy, of course, was aware that, owing to increase of distance, the sun would appear to an inhabitant of Saturn with a disk only one ninetieth as great in area as that which it presents to our eyes.

[12] For further details about Saturn's rings, see The Tides, by G.H. Darwin, chap. xx.

[13] The Tides, by G.H. Darwin, p. 333.

[14] Ikaromenippus; or, Above the Clouds. Prof. D.C. Brown's translation.

[15] The Moon, a Full Description and Map of its Principal Features, by Thomas Gwyn Elger, 1895.

Those who desire to read detailed descriptions of lunar scenery may consult, in addition to Mr. Elger's book, the following: The Moon, considered as a Planet, a World, and a Satellite, by James Nasmyth and James Carpenter, 1874; The Moon, and the Condition and Configurations of its Surface, by Edmund Neison, 1876. See also Annals of Harvard College Observatory, vol. xxxii, part ii, 1900, for observations made by Prof. William H. Pickering at the Arequipa Observatory.

[16] The discovery of free hydrogen in the earth's atmosphere, by Professor Dewar, 1901, bears upon the theory of the escape of gases from a planet, and may modify the view above expressed. Since hydrogen is theoretically incapable of being permanently retained in the free state by the earth, its presence in the atmosphere indicates either that there is an influx from space or that it emanates from the earth's crust. In a similar way it may be assumed that atmospheric gases can be given off from the crust of the moon, thus, to a greater or less extent, supplying the place of the molecules that escape.

[17] Comptes Rendus, June 26, July 3, 1899.

[18] The Tides, by G.H. Darwin, chapter xvi.

[19] Annals of Harvard College Observatory, vol. xxxii, part ii, 1900.

[20] Comptes Rendus, June 23, July 3, 1899.

[21] In our latitudes, planets are never seen in the northern quarter of the sky. When on the meridian, they are always somewhere between the zenith and the southern horizon.

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THE END

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