A DAY IN THE MOON

Rolfe

A DAY IN THE MOON

From a drawing by the Abbé Moreux.

THE EARTH AS SEEN FROM THE MOON.

(The landscape shows part of the range of the Lunar Alps.)

[*Frontispiece.*

A DAY IN THE MOON

BY THE ABBÉ TH. MOREUX

Director of the Bourges Observatory

WITH 40 ILLUSTRATIONS FROM PHOTOGRAPHS AND DRAWINGS

New York

FREDERICK A. STOKES COMPANY

PUBLISHERS

PRINTED IN ENGLAND

CONTENTS

ILLUSTRATIONS

The Publishers are indebted to the kindness of the Author for the loan of many of his original drawings for reproduction in this English translation.

IN THE TEXT

A DAY IN THE MOON

I

THE MOON

To launch out into space, to rise ever upwards, to leave the Earth far away and fly on strong wings to the Moon, to descend upon its silvery surface, traverse its unknown plains and valleys, examine in detail the structure of that globe which we see suspended above our heads, and at last to come back and tell the people of the Earth the daring adventures of that distant journey . . . what a dream!

We have all had such dreams on some autumn evening when, as we returned in thoughtful mood from some long walk in the country, the thin crescent of the new Moon rose on the background of the sky, still tinted with the twilight glow.

And this reminds me of an evening in one of the vacations I spent in the Sologne, my native district. I had accompanied my father on one of those walks of which he was particularly fond, and during which he never missed an opportunity of developing my interest in the various phenomena that Nature is each moment placing before our eyes.

Behind us the sun had set and night was coming on with a perfectly clear sky. We were walking along a footpath among clumps of heath and furze. A herdsman was singing as he slowly brought back his cattle to their shed, and gradually as the night came on the thousand sounds of Earth were hushed. One might have said that Nature was assuming a recollected silence the better to prepare man to feel the charm of the heavens that were soon all studded with stars.

And now, as the tints of the landscape faded away, my childish imagination was full of delight.

The wide unbroken plain extended to the horizon, which it seemed to touch, and I thought that the sea must present much the same appearance. Here and there the thickets of high-growing shrubs stood out in dark patches on the ground, and I imagined they were like great waves. The clumps of pines scattered here and there farther off, black, ill-defined masses rising over all else, seemed to me to be big ships with their masts swaying gently in the light evening breeze.

Suddenly a glow like that of a fire gleamed out beyond them, the ruddy disc of the full Moon rose above all the things of Earth, and immediately my mind was prompted to other thoughts.

Why is it that the Moon does not always appear to be round?

What is the explanation of its phases?

I knew that with the naked eye one could only have a very rough idea of its aspect, and I had often levelled at its shining disc a telescope of very moderate power, the only astronomical instrument then in my possession.

Those greyish spots that one sees with the naked eye appeared more clearly defined even with a magnifying power of only ten, but my telescope was hardly powerful enough to show me the lunar craters and mountain-walled plains. I thought indeed that I could catch glimpses of them, but nevertheless I was always ambitiously dreaming already of more powerful instruments.

I used often to ask myself at that time if it was true that the Moon was strewn with giant mountains, that a man could walk and stand on its surface and photograph its landscapes? And those "craters" that had been discovered in our satellite, had they really been volcanoes in earlier ages?

If man had existed in the times of the Brontosaurs and the Iguanodons, would he have been able to make out the jets of fire and smoke in lunar eruptions?

Why did this heavenly body revolving around us always present the same appearance since man first observed its enigmatical surface?

On our Earth generations succeed each other. Man has spread over and peopled the globe. And each evening the tillers of the soil returning to their farms look up to the sky.

At the hour when in the cities of civilised lands artificial light blots out the stars and deprives the town-dweller of that spectacle of the universe, the countryman can gaze on the starry sky, and he always asks himself the same questions without making any attempt to solve them. At school he is taught to divide up the Earth into separate compartments. He learns by heart the exploits of blood-stained heroes. He knows the date of the battle of Crécy, when for the first time cannon made their appearance hurling their deadly bolts. He is told of the properties of explosives and the principle of the bullet in the modern rifle.

And those who possess riches no longer live in contact with Nature. Fashionable gatherings, plays, race-courses, theatres, are the chief interest of their aimless and unprofitable pursuits.

The literature of the day reflects this idle and useless life. Most of our works of fiction display in the full light of day the blemishes of a decadent Society, and under the pretext of psychological analysis describe the disorderly outburst of passion.

There is material and industrial progress everywhere, and this is a good thing, but moral progress does not keep pace with it. Men neglect the study of Nature, and lose touch with its manifestations, which are capable of leading them infallibly to a consideration of the great questions of science and philosophy.

Since the days of the Egyptians and Greeks and the other peoples of antiquity with whom our civilisation began, the mass of men have remained quite ignorant of the great questions which are alone worthy to occupy a thoughtful mind.

Man, bowed to the Earth, no longer looks upon the Heavens and no longer pays homage to his Maker.

Question a thousand of the inhabitants of our planet and ask them where they are in the universe, speak to them of the Solar System, of Jupiter, of Saturn, or of the stars—hardly one, at most, will understand you and grasp the fact that there are other subjects of interest beyond that of our trifling daily occupations.

From the astronomical point of view nearly all of them have remained, so far as this goes, not at the epoch of Pericles or Augustus, but at that of the Stone Age.

And meanwhile what wonderful progress has been made by all the physical sciences in general—progress by which Astronomy has been the first to benefit.

We can now answer questions of which the solution once seemed to be a thing of insurmountable difficulty.

The discoveries in physical Astronomy have told us more and more of the marvels of far-off worlds.

And as for those that lie nearer to this Earth of ours, we are able to examine them with magnificent instruments. They are part of our own system, and are linked with our lot in the universe, and, to adapt the saying of an ancient philosopher, "nothing that concerns them ought to be without interest for us."

Science has in a measure realised that dream of visiting worlds so different from our own, thanks to the penetrating power of the instruments it places at our disposal.

We can now enter on detailed studies of each of the planetary bodies, and as the Moon is of all the lights of the firmament the one nearest to us, it is natural to begin our excursions in the heavens with this neighbouring world, which the laws of attraction link with our planet by bonds as subtle as they are mysterious.

II

OBSERVATIONS OF THE ANCIENTS

Whatever may be said to the contrary, it is not at all certain that the powers of the human intelligence have made any very notable progress since the first appearance of man on the Earth.

We have no doubt that there were among the ancients men of superior intelligence from every point of view, and the study of their writings, their pursuits, their theories, is well calculated to throw a new light on our recent discoveries and at the same time help us to realise the imperfection of our knowledge.

When it is a question of studying a science, the only acceptable method is that of following its development and its evolution through the various periods of history. Such a method will at once show us that each science grows like a living creature. Each important step of progress is always the outcome of long preparation, and never comes suddenly, just as in the living organism the useless elements are got rid of and give place to new substances.

We shall have many examples of this in the course of our familiar talk about the science of the Moon, or as it has been called, *Selenography.*

Without speaking of the dreams of mythology, that assigned to the Moon the personality of Selene or Diana, and told how the Nemean lion came from our bright neighbour to terrify mortal men, it is very interesting to examine the opinions of the ancient world about our satellite in times when the telescope was a completely unknown instrument.

Achilles Tatius, who wrote three centuries after Christ, has recorded for us the opinions of his immediate predecessors. For some of them the Moon was merely a detached fragment of the Sun—in days nearer our own Laplace could find no better theory. According to others, it was formed of exhalations from the earth which took fire in the upper regions of the heavens.

In a passage of his translation of Plutarch, Amyot tells, quoting a disciple of Aristotle, how the latter held that "the forms and images of the great sea of the Ocean appeared in the Moon as in a mirror."

Many of the ancient philosophers had remarked the connection between the phases of the Moon and its position with respect to the Sun, and this idea of comparing the Moon to a mirror had become current among them. So the author just quoted says that "in its polished brightness it is the most beautiful and clearest mirror in the world."

All these fancies were very far from reality, and the first astronomical telescopes were destined to give some astounding surprises to the old astronomers.

The telescope was not, it is true, first invented by Galileo, but it is to this man of science that the honour belongs of having been the first to apply the instrument to the study of the heavens.

There can be no doubt of this, and Galileo himself tells the story in his *Sidereus Nuntius*, which appeared in March 1610:

"About ten months ago I was informed that a certain Dutchman had devised a telescope, by means of which he saw distant objects as plainly as if they were near at hand. This instrument had already been used to make a number of experiments, to the results of which some gave credit while others denied them.

"And this was confirmed for me some days later by a letter which the Frenchman, Jacques Badovère, addressed to me from Paris. All this finally led me to devote myself entirely to studying the means

GALILEI GALILEO
(1564-1642).
After the portrait painted and engraved in 1624 by Ottavio Leoni.

of arriving at the application of a similar device; and I, in fact, succeeded therein shortly after, with the help of the theory of refraction. First of all, then, I made a leaden tube, to the ends of which

I fitted lenses, both of which had one plane surface, while the other side of one of them was convex and that of the other concave. Then bringing my eye to the concave lens, I saw objects looking near enough; these objects appeared three times nearer and nine times larger than with the unassisted sight.

"I then made a more carefully finished instrument, which magnified the objects more than sixty times.

"Finally, sparing neither trouble nor expense, I succeeded in making for myself an instrument so excellent that it enabled me to see objects a thousand times larger than with the unassisted sight."

With regard to the magnifying powers of which Galileo here speaks, we must go into some details that are necessary for the understanding of this somewhat ambiguous passage, and which will make clear the meaning of an expression that frequently recurs in dealing with astronomical subjects.

Take a square of which each side is an inch in length and double these linear dimensions. What shall we have?

Each side of the new square will be two inches in length, and the surface, which originally measured one square inch, will have become $2 \times 2 = 4$ square inches.

Thus, in doubling the linear dimensions one quadruples the surface; if one lengthens the sides threefold, the surface becomes $3 \times 3 = 9$ times larger.

It has now been long an established rule in physics that the magnifying power of instruments is always to be stated in linear units. When we speak of a microscope magnifying twelve times, we mean that in the object under examination each dimension appears twelve times longer.

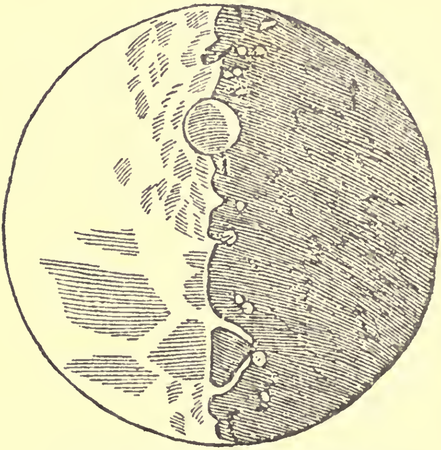
Galileo, doubtless to strike the imagination of his contemporaries, purposely had recourse to the method adopted by certain dealers in optical instruments, who advertise microscopes magnifying 144 times, but carefully omit to add "superficially"—the corresponding linear magnification being only twelve times.

This principle applies to objects of other forms than a square, as, for instance, a polygon or a circle.

Galileo's first telescope magnified the surface nine times; that is to say, three times, estimating by linear units.

Later, it is true, he constructed instruments magnifying the diameter of celestial objects thirty-two times; that is to say, $32 \times 32 = 1{,}024$ times superficially.

These instruments are now kept in one of the museums of Florence.



THE FIRST PICTURE OF THE MOON.
DRAWN BY GALILEO IN 1610.

Galileo was at Venice when he heard of the discovery of the telescope. He at once returned to Padua, where he held a professorship of Mathematics, and it was there that he constructed his first instrument with lenses that he happened to have in his possession.

Later on he presented a telescope magnifying thirty-two times to the Doge Leonardo Donati, and then another of the same kind to the Grand Duke of Tuscany.

The Venetian Senate, in its admiration for his invention, confirmed him for life in his professorship at a salary of 1,000 florins a year; and the Grand Duke of Tuscany lavished gifts upon him.

"It would be superfluous," continues Galileo, in the passage already quoted, "to reckon up the advantages to be obtained by the use of this instrument on land as well as at sea. But leaving aside these terrestrial things, I have directed my researches towards the heavens, beginning with the Moon."

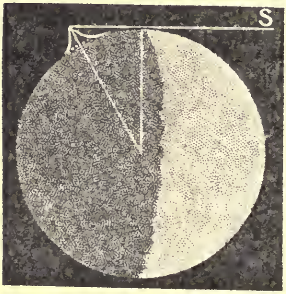
And what Galileo saw might well excite the wonder of his contemporaries.

He first of all discovered mountains, more or less brilliant spots and circular hollows, which he compared to the eyes in a peacock's tail.

At the moment of the phases the boundary between the dark part and the light appeared to him under the form of an irregular, uneven line, and he drew from this the logical conclusion that the Moon was far from being a perfectly smooth sphere. But then, how was one to explain the fact that at the moment of Full Moon the margin showed neither projections nor hollows?

For this question Galileo found two answers—which were incorrect. He said that either the Moon had an atmosphere which enlarged the apparent size of its disc and made its marginal irregularities disappear, or else the mountains seen in perspective concealed each other.

In reality he ought to have noted that only when an object is illuminated from the side it throws a shadow that makes its summits stand out and reveals its irregularities.



METHOD OF MEASURING THE HEIGHT OF A LUNAR MOUNTAIN.

With our actual telescopes the outer edges of the Moon are far from being as regular as they appeared with the telescopes of moderate power in use at the beginning of the seventeenth century. We have, however, to thank Galileo for having noted another and a very important phenomenon, which put him on the track of an ingenious method of measuring the height of the lunar mountains.

On account of the surface of the Moon being convex, when the sun rises upon one of its regions the rays first light up the lofty summits of the mountains. An astronomer looking from the

THE NORTH HORN OF THE MOON.
(Reversed image.)

Earth sees, therefore, a luminous spot separated from the bright part of the Moon by a dark band corresponding to the valleys still plunged in shadow.

But under these conditions it is easy to take the line of a solar ray as a tangent to the curved surface of the Moon ; this straight line touching the mountain summit forms with two lines drawn to the centre of the moon (one vertically through the summit, the other from the point where the ray first touches the curved outline of the moon) a right-angled triangle, of which the length of the sides can be ascertained. Then a simple calculation gives at once the height of the illuminated summit (which is equal to the difference between the two lines drawn to the centre of the moon).

The study of the shadow thrown by a lofty peak would lead to the same conclusions, and since the time of Galileo astronomers have not failed to improve and perfect these methods.

But however this may be, it is certain that in 1610 there was a complete revolution in accepted ideas as to the nature of the Moon. Thanks to Galileo's discoveries, it became impossible to deny that our satellite presented the appearances of a world in many ways resembling the Earth, and with a surface standing out in higher relief in certain regions.

But did this miniature of our planet possess seas, rivers, and forests ? Was it inhabited ?

This was something that could not yet be decided by observation, and the savants of the time could give free rein to all the fancies we permit to romancists and poets. Such a fine chance was not lost, and voyages to the Moon supplied to authors a subject all the easier to dilate upon because there was a complete absence of positive facts.

But was Galileo, as is so frequently stated, the first to distinguish the mountains of the Moon ?

History, as has often been said, is nothing but a perpetual beginning again. Was this comparatively recent invention of instruments, that make objects appear nearer, anything more than a rediscovery, and are we to believe that the ancients were entirely ignorant of the use of magnifying glasses and even of some kind of telescope ? This is a question that we may examine together before closing the chapter.

Anaxagoras, according to the account of Diogenes

Laertius, asserted that there were mountains, valleys, and inhabitants in the Moon.

This passage has generally been regarded as a piece of mere fancy, but who can say whether, when he wrote these lines, the author of the Orphic poems was not echoing an old tradition that came from Egypt, Phœnicia, or Chaldæa?

The best-established scientific ideas can be lost as the old civilisations were; and it seems to me interesting to give here the results of a study I made some time ago of this little-known chapter in the history of Optics among the ancients.

First of all, was glass known to the peoples of antiquity? This point appears open to no doubt.

There is a passage in the writings of Aristophanes in which he relates that in his time globes of glass were sold by the grocers in Athens. At a later date Pliny tells how the immense theatre erected at Rome by Scaurus, the son-in-law of Sylla, which could hold 80,000 spectators, had three sets of seats rising above each other, and those of the second series were entirely covered with mosaics in glass.

In the seventh book of his Recognitions the pseudo-Clement relates a legend of St. Peter having gone to the island of Aradus and seen there a temple with columns of glass of extraordinary height and thickness, which excited his wonder even more than the splendid statues by Phidias with which this temple was adorned.

Seneca, in his *Questions on Nature*,[1] speaks of the phenomena of the colours seen when one looks slant-wise through the projecting angles of a piece of glass. At this time, therefore, the prism and the production of colours by refraction were known.

In the reign of Nero cups of cut rock-crystal were in use. The tear bottles found in the tombs are also made of glass, and at this period it was on glass globes that the celestial spheres and the constellations were marked out.

In his Optics, Ptolemy inserts a table of the refraction of a ray of light in passing through glass. Now, the indices of refraction given in our modern works on Physics approximate so nearly to his, that we must conclude that the glass of his time differed very little from that which we make nowadays.

[1] *Quæstionum naturalium*, libri vii., the only surviving Roman treatise on physics.—*Translator's Note.*

All these are certain facts. But it will be said that they do not prove that the learned of antiquity knew the properties of lenses.

Granted ; but here is some other evidence.

Everyone has heard of the emerald through which Nero watched the games of the amphitheatre. Aristophanes in his comedy of the *Clouds* makes a curious jest. In the play Strepsiades explains to Socrates the possibility of setting fire to combustibles by means of a glass globe. And this ingenious person tells how he has found a way of avoiding the payment of his debts by thus, from a distance, destroying the acknowledgments in the hands of his creditors, without their being able to find him out.

The Romans, who had learned science from the Greeks, instead of caustic, used globes of glass exposed to the sun for cauterising flesh. And if the Vestals negligently allowed the sacred fire to become extinguished, it was their duty to rekindle it by means of the heat of the sun concentrated through little glass spheres.

When in 1905 I was sent by the French Government to Tunisia to observe the total eclipse of the Sun, I took advantage of my stay at Tunis to pay a visit to Père Delattre, who, as is well known, has with admirable patience brought together in a museum, that is unique in the world, the materials for a reconstruction of Carthaginian civilisation.

My colleagues and myself were not a little surprised at being shown, amongst other remarkable objects, a cameo carved as an intaglio, with a design of singular perfection. It represented a horse scratching its head with its hind hoof. The minute details of the mane suggested to me the idea that the artist must have used a magnifying glass when carving it. And it actually was with a plano-convex lens of rock-crystal, found in a tomb of the same period, that we were able to examine the cameo in detail. I have since learned that this is not the only instance of the same kind.

There is in the French *Cabinet des Médailles* a seal attributed to Michel Angelo, but which is really of much earlier date. Fifteen figures are engraved on it in a circle of a radius of only 7 millimetres.[1] These figures are not all visible to the naked eye.

Cicero relates a still more extraordinary fact.

[1] A little more than a quarter of an inch (0·275 in.). The diameter would thus be about half an inch (0·55 in.).

He tells of an artist having written out the whole of Homer's *Iliad* in microscopic characters.

One may judge of the minuteness of the work, when it is added that, according to the same author, the piece of parchment could be contained in a nutshell.

Pliny also relates that Mymecides had sculptured in ivory the representation of a four-horse chariot so small that a fly could have covered it with its wings.

The Greeks and Romans must therefore have known the magnifying power of optical lenses.

If there were any doubt of this, we need only recall the story of that magnifying glass in the Carthage Museum. In the same cases of the museum one can see similar lenses made of glass, but these have become opaque with the lapse of time.

But as long ago as 1852 Sir David Brewster exhibited, at a meeting of the British Association, a lens of rock-crystal, which had lately been found in the excavations of Nineveh.

It is therefore quite natural to suppose that the ancients might very well have reached a knowledge of optical instruments such as microscopes and telescopes, all the more because what is essentially required for such instruments is only the placing together of a couple of magnifying lenses.

There is all the more to be said for this theory because if we deny to the peoples of antiquity this useful knowledge, it is impossible to explain a good many statements they make—amongst others, this which I take from Democritus. This philosopher affirmed that the Milky Way was made up of a countless number of stars, and that it was the confused mingling of their light that was the cause of its phosphorescent whiteness. How could Democritus have imagined such an explanation at a period when the nations of his time still believed in the legend of the drops of milk from the breasts of Juno?

It may be that the ancients even knew something of the reflecting telescope, the instrument made with a concave mirror. And this supposition is not more unlikely than the other.

Some writers appeal in support of this idea to the burning mirrors that Archimedes used at the siege of Syracuse to set on fire the ships of Marcellus.

But it seems to be now fairly well ascertained that the mirrors in question were not concave, or of a single piece, but formed of a great number of flat reflecting surfaces at various angles concentrating the solar rays on the same point.

Such an arrangement can produce the same concentration of heat as the concave mirror of a telescope, and Buffon, by means of 148 plane mirrors, once succeeded in setting fire to a deal board at a distance of 49 metres (about 160 ft.).

Critics have, however, always been very reserved when it comes to the question of explaining a statement made by serious historical writers regarding vision by means of some unknown apparatus.

Ptolemy Euergetes, the brother of King Ptolemy Philadelphus, who lived in the third century before Christ, had caused to be fixed on the summit of the lighthouse of Alexandria an instrument with which ships could be seen at a great distance. Many authors have suggested that this may have been a concave mirror.

The thing is quite possible, but it must be added that a mirror of this kind could be of no use whatever for bringing distant objects near without the addition of a lens. But there is no reason why such an optical device should not have been adopted at this period. This is shown by the evidence already cited.

When therefore Galileo directed his telescope at the Moon, it was perhaps not the first time that man had made celestial objects seem nearer to him, and who can say if the priests of old Egypt may not have watched from the summits of their observatories the last eruptions of the lunar volcanoes ?

III

THE MOON AS SEEN BY THE NAKED EYE

One September day some years ago I was in Paris taking a quiet walk along the quays by the Seine, when there suddenly came to me the idea of making a long journey. I had three weeks in front of me, more than is necessary for getting far away from the capital.

On one point only I was embarrassed. Where was I to go?

But two hours later I was in the express on my way to Amsterdam. I had taken the first train I found starting from the Gare du Nord.

And this was how I came to visit Holland.

But I would not now advise anyone to adopt this way of setting out on a journey.

Those who study in advance the regions they are about to visit (and there are many who do so) seem to me to be much better advised.

Let us imitate those serious and sensible people, and before setting out for the Moon let us study together the facts that are essential for the understanding of the celestial phenomena connected with our satellite.

And, first of all, what is a *satellite*? What is the meaning of this word that we so often apply to the Moon?

You know that the Solar System is composed of a great central body round which revolve certain planets, smaller than itself.

Now, these planets are in several cases accompanied in their stately movement of revolution by other stars smaller than themselves, as a kind of bodyguard.

The number with each planet varies. Mars has two of them, Jupiter eight, and a telescope of very moderate power will show you the four largest of these.

If we could go away some hundreds of thousands of miles from our Earth, we should see that it was, in the same way, accompanied in its rapid course by a single satellite. This only child of our dear mother Earth is the Moon.

Let us go back in imagination several thousand centuries to the time when the Earth, a vast globular mass of gas at a high temperature, shone like a miniature sun.

Beside this relatively small star there would be not a trace of a satellite, but around it an immense ring of diffused matter resembling, though of more restricted dimensions, that which we see in the nebula of the constellation *Lyra*.

Ages pass by, and the spectacle has gradually changed. There has been a movement of the Earth's axis, and now all the material of its primitive ring, instead of lying in spirals around it, has concentrated into a single compact mass. The ring has been the origin of a very small luminous body revolving round that star—the Earth.

Earth and Moon at this epoch shone with a brightness that was all their own. They formed in the heavens one of the lesser double stars, of which the component units are linked together by the laws of attraction.

To analyse what must have taken place under these new conditions of existence is a problem of celestial mechanics that is easy of solution.

First of all, like all the heavenly bodies, the Moon turned on its own axis—that is to say, to its movement of revolution, making it follow an orbit round the Earth, there was added a movement of rotation on itself completed in the course of a few hours.

But when two bodies in a fluid state are in presence of each other at a moderate distance, an elongation of their shape is produced, a kind of spreading out in the direction of the line joining them together ; it is the same phenomenon as that of the tides, and each region as it passes before the attracting body is in turn influenced by it.

Now, the mass of the Earth is enormous in comparison with that of the Moon, and accordingly at this remote period the tides of the satellite must have been produced with extraordinary intensity.

Thus at each turn of its rotation the convex distortion of the lunar mass under the attraction of our globe would act just like a brake applied to the Moon, generally retarding its motion, so that the final result of this phenomenon would be that the time of its rotation on its axis and its revolution round the earth would gradually become equal.

From a photograph.

EARTH-LIT NEW MOON.

At present things go on just as if the Moon were fixed to the Earth by an enormous arm keeping it in the same relative position, and checking any deviation to right or left.

And this is why we always see the same side of the Moon.

The ancients had long ago noticed this fact, which you yourself can test by observation with the naked eye, especially at the time of the Full Moon, when you will see that the spots are always arranged in the same way.

From remote times the peoples of antiquity traced in it a kind of human face with two eyes, a mouth, and a nose. Sometimes, as nowadays, men took the appearance to be that of a man bending under a burden.

Albertus Magnus has left us a description of the Moon which is extremely precise for a time when the human eye was not aided by magnifying instruments. Well, this description corresponds very exactly with what an astronomer of to-day would say.

So the Moon, since man appeared on the Earth, has always presented the same side to us.

Are we to conclude from this that it does not rotate upon itself? If you please, do not jump to hasty conclusions, but let us examine the question more closely.

Walk round a table in the middle of which you have placed something, and don't take your eyes off this object, which will represent the Earth, while you are playing the part of the Moon.

When you have gone half-way round, it is evident that you will be facing the wall of the room that was behind you at the beginning of the experiment. Thus, without paying attention to it, you will have already yourself turned half-round.

Finally, by the time you have come back to the point you started from, you will have completed one round "of your orbit," and at the same time you yourself will have turned completely round, just as if you had made a slow pirouette on your feet.

There would be just the same sort of thing if a balloon could go all round the world. When they reached the Antipodes the aeronauts, compared with ourselves in the north, would be head downwards, and by the time they returned to our regions they would have slowly made a regular somersault, like the clowns in a circus.

And nevertheless during all this voyage men remaining below on the Earth would see only the lower part of the balloon, which would always keep the same side towards them, just as the moon does.

"Well, then," you will say, "we are condemned never to have a sight of the other hemisphere of the Moon?"

"Evidently."

"Has it the same structure as that which we can see—craters, mountains, valleys, etc.?"

This is a point to which we shall return later on.

The other side of the Moon, precisely because we cannot see it, and shall never see it—at least unless we go there—has always, like all unknown things, exercised a mysterious attraction on selenographers, and we shall refer to it again.

Let us come back, then, to the subject of the appearance of the Moon.

I have met many persons who do not even yet understand why the Moon does not always appear under the form of a perfectly circular disc. They have remained in the same state of knowledge as was that of remote antiquity, or rather they have no ideas on the subject. They don't know, and they are not anxious to know.

The Chaldæan astronomer Berosus, to explain the phenomenon, supposed that the Moon was a globe half alight and half dark, and that in turning upon its axis it showed us these different regions in succession.

However, there were, even before Berosus, philosophers who knew better, and had found out the true explanation.

Thales had perfectly well noted that the Moon received its light from the Sun, and later Aristarchus rightly remarked that at the moment when the Moon was half lighted up, the Earth was exactly opposite the dividing line between light and darkness, while the direction of the Sun was at right angles with the line between Earth and Moon.

Make the experiment yourself with a white ball hanging by a string in a room lighted by a single lamp, and you will soon succeed in working out the position of which Aristarchus speaks.

This able mathematician did even better. From this observation he deduced a method of measuring the distance of the Sun, and he found that it was nineteen times greater than the space that separates us from the Moon.

He had made a mistake in the application of

Photograph by the Lick Observatory.

THE MOON AT THE FIRST QUARTER
(Aged 7 days 3 hours).

his idea, but in principle it was right enough, and Kepler more than once recommended this method.

Vendelinus and Riccioli made use of it, but without any more success. In a telescope the Moon in fact does not appear as a perfectly even sphere, and the irregularities of its surface make it hopeless to fix any precise moment when the line between light and shadow is really a straight one.

But, on the other hand, the invention of the telescope in 1610 removed all possible doubt as to the explanation of the Moon's phases.

In the field of view of the instrument it was in fact easy to follow hour by hour the flooding of new regions of the Moon by the Sun's light.

And, nevertheless, though one can hardly believe it, in 1613 Albergotti still taught, as a professor of Astronomy, that the Moon gave a light of its own, and to prove this he appealed to Biblical texts which he interpreted in his own way. This mania for mixing, without any reason, Holy Scripture and scientific theory (from which, by the way, Galileo himself was not exempt) seems to us nowadays extraordinary. And, nevertheless, I have come across it more than once, as is shown by many letters I have received on the subject.

A little reflection, seasoned with some extremely simple experiments, will show us the real mechanism of the phases of the Moon.

Let us take once more our white ball, hanging on a string and held at arm's length, with a lamp placed on a table on a level with the eye, and, without moving from the spot where you stand, carry the ball in a circle round your head, which will represent the Earth.

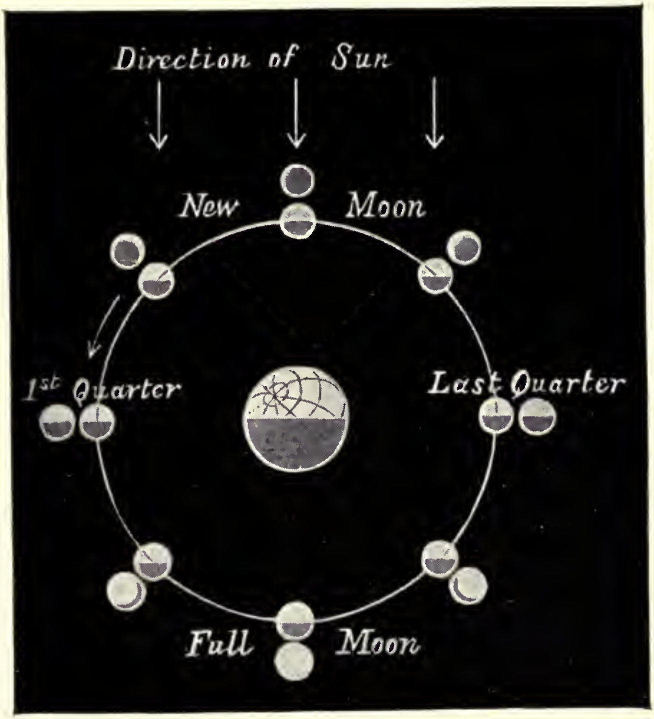
Only you must take care to keep the ball a little above the level of the eye, for the Moon moves in an orbit slightly inclined to the path followed by the Earth.

Let us begin with the position of Full Moon.

The ball is at the other side of your head from the lamp. Facing it, you see that it presents a disc entirely illuminated.

As you move it from this position you begin to perceive a narrow segment of shadow, cutting off a little of the illuminated circle. As you continue the movement in the same direction you arrive at the Last Quarter, and the boundary line between the shadow and the light will divide the disc into two equal parts, the lighted part being to the left.

Again a slight movement, and the shadow will



The Phases of the Moon.

gain further ground, and soon leave only quite a thin crescent. As soon as the Moon is in the same direction as the Sun, above or below it, it turns its dark side to us and the disc entirely disappears. This is the Old Moon.

Starting from this position we have the phases in reversed order, and we come to the First Quarter, and then the Full Moon, and so on.

If the experiment is reversed, going round the ball held at arm's length so that your head represents the Moon, you will see that our Earth would present to the Selenites[1]—as we might call the inhabitants of the Moon, if there were any—similar phases, but in the opposite order.

In other words, when, for instance, after the New Moon the people of the Earth see their satellite under the form of a crescent, the Selenites would see the Earth in its last quarter, that is to say three-fourths illuminated.

And this remark will explain to you why at this period of the lunar month we see not only a thin and very bright crescent, but sometimes the rest of the Moon dimly illuminated by the diffused reflection from the Earth.

[1] From *Selene*, the Greek name for the Moon.—*Translator's Note.*

This is what is called the "earth-shine" on the Moon.

We have said that the Moon revolves in an orbit obliquely inclined to the plane of our own. The inclination is slight—only 5° 8′—but it is nearly constant. The result is that the Moon does not always pass precisely between us and the Sun. If it passes at a point where it hides that brilliant disc from us, there is an eclipse of the Sun. If, on the other hand, when passing on the opposite side of the Earth, it is hidden in the shadow of our planet, there is an eclipse of the Moon.

These two phenomena therefore take place only at the time of New or Full Moon, and they recur in a series that extends over about eighteen years.

These are extremely interesting topics from the astronomical point of view, and we shall return to them. But we shall end this chapter with an attempt to solve a question which has caused the expenditure of floods of ink since first men became interested in it.

Why does the Moon appear larger on the horizon than when at its highest point?

I have said "appear larger," because this is certainly a mere optical illusion.

Photograph by P. Puiseux, Paris.

THE MOON

(Aged 8 days 23½ hours. February 6th, 1903, 4.3 a.m.).

In reality its disc is larger when in the zenith, the highest point of the sky, than it is near the horizon, as is shown by measurements made with a micrometer fitted to a telescope. And this is what theory should lead us to expect, for the Moon in the zenith is slightly nearer the observer. But this very small difference is quite unappreciable to the naked eye, and we may say, still keeping close to the exact truth, that as seen by us the Moon always occupies precisely the same amount of space in the heavens.

Then why does it seem to us larger when it is near the horizon, and apparently therefore near the Earth?

And remember that this phenomenon is not something special to the Moon. The Sun in the same position also appears larger to us, and finally the constellations themselves seem to occupy more space when they are to all appearance nearer the ground. The most humble student of the heavens can see this for himself any evening if he will observe the Great Bear at different hours of the night.

There are plenty of theories to explain such appearances. One of them is based on the fact that we cannot avoid mistakes in judging distances accordingly as the background, on which the object is seen, is bright or dark. And a fog makes objects seem larger because it makes them seem farther off. Here is an instance of such a mistake from my own personal experience.

One summer day about dawn I was taking a walk with a friend in a country that neither of us knew well. The road rose steeply in front of us, and where its highest point met the sky-line we saw, coming into sight over the crest, what looked like someone in a rather short dress, such as the countrywomen wear in many parts of the province of Berry. We were for a moment in doubt as to what kind of person we were about to meet. I bet that it was an ecclesiastic in a soutane, my friend that it was a peasant woman. But the distance between us and the subject of our wager was not at all as great as we imagined. We were soon close up to the "person" in question. We had both lost our wager. For a goose was walking in stately fashion down the middle of the road, with its head directly towards us. The twilight haze had deceived us as to the real distance, and the object, projected against what we thought to be a far-off background, had assumed an enormous size.

From a photograph.

THE FULL MOON.
(Aged 14 days 1 hour).

It is true that at the moment when one of the heavenly bodies is rising its rays reach us after traversing a denser layer of the atmosphere than when it is nearer the zenith; its brightness is diminished and it appears larger to us. But this is only an imperfect solution of the problem. For, as a matter of fact, when the bright disc shows dull and grey through a dense fog it never gives us the same impression of size as the broad sunset Sun. Fog and haze, therefore, do not explain everything.

Another theory is based on the absence of points of comparison, when the Sun or Moon are at the highest points of their course.

As it rises, the Moon is seen as a part of the landscape, and we have objects close by with which to compare it. There are none of these as it approaches the zenith. It seems to be nearer us, and though its apparent diameter has not really changed, we think it looks smaller.

But here again we have not the real key to the riddle. For at sea in calm weather, especially in the evening, though there are absolutely no objects with which to compare the size of the setting Sun, the illusion remains just as strong. It is the same on a plain, where there is not a tree or a house to help the observer's estimate.

We must therefore, as I have shown long before this, have recourse to a theory based on psychological principles, and my explanation rests upon two optical illusions that it is easy to test.

In the first place, the firmament—that is to say, the ideal vault to which, whether we will or not, we attach in imagination all the stars, as if they were equally distant—seems to us a flattened curve and not spherical.

The reason is very simple. For us the Earth seems always flat, though we well know the contrary, and the masses of cloud carried overhead by the wind appear some hours later to touch the horizon.

Now, above the clouds we place the stars, and we instinctively imagine the vault of the clouds and the stellar vault as parallel curves, and thus both are for us flattened arches bending down to the horizon, so that there the heavenly bodies would be farther off than at the zenith.

If I am met with the objection that even with a clear sky there is the impression of the vault of the heavens being flattened in the same way, I find

Photograph by P. Puiseux, Paris.

THE MOON

(Aged 20 days 19 hours. September 12th, 1903, 3.13 a.m.).

an explanation in the fact that we have no means of estimating distance in the sky, and, whatever be the explanation accepted, the error and illusion persist. The arch appears to us flattened at its upper part.

In the second place, it is undeniable that the apparent dimensions of an object are greater when we project it upon a more distant background.

Do you want an example? In the evening look fixedly at the incandescent filament of an electric light close to you. Then suddenly cast your eyes on a more distant object, the front of the opposite house seen through the window, or something still farther off. The image of the lamp, still seen by your eye, will seem enormous, and will occupy a considerable surface of the dark background.

Here is the whole solution of the problem, and I sum it up in a single phrase: the Moon seems to us larger on the horizon simply on account of the apparently flattened or elliptic form of the sky.

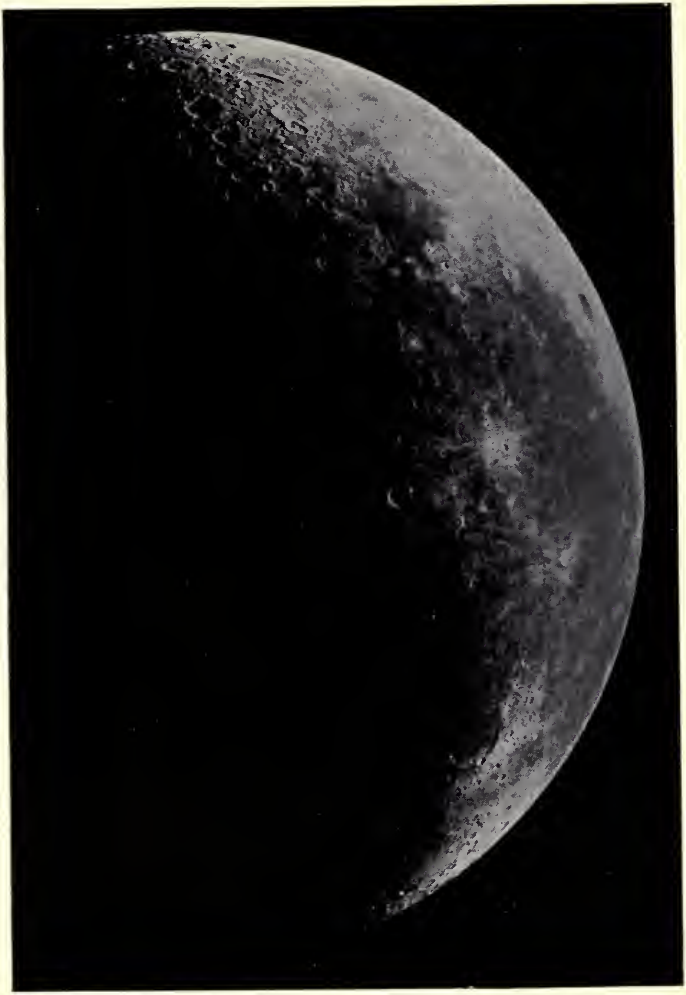
Since I first stated this theory some astronomers have sought for other explanations, and I have found a better proof of my hypothesis.

When the Sun is setting in a clear sky and your eyes can easily endure its brightness, fix them for a few moments on its still brilliant orb, then look at another point of the horizon. Your retina will present to you a dark spot, green, bluish, or black, and you will be able to keep sight of it if you take care frequently to wink your eyes.

Note attentively the apparent size of this subjective image. It will naturally appear to you of the same size as the solar disc, but—and here we have a complete confirmation of my theory—if at this moment you turn your gaze towards higher and higher points of the sky, the same image will appear to be diminished in size, and it will reach its minimum surface when you see it at the zenith.

Here we have the solution of all difficulties, and we may conclude with a somewhat picturesque passage from the letters of Euler to a German Princess :

" I believe," he said, with reference to the subject that has occupied us, " that I have placed in its true light the difficulty with which we have had to deal in this matter, so as to make your Highness the better appreciate the importance of the true solution of this great problem."



Photograph by the Lick Observatory.

THE MOON AT THE LAST QUARTER

(Aged 23 days 8 hours).

IV

WITH THE EYE AT THE TELESCOPE

HERE we are at our fourth chat about "lunar matters," and we have already made serious progress in the study of our satellite, from the mechanical point of view.

Let us sum up rapidly what we have learned; this will help us not to forget, and give us the opportunity of adding something to it.

At the outset the materials which were later on to form the Moon were distributed in the shape of an immense ring encircling the Earth at a distance. The Moon was therefore never a part of the Earth as the celebrated Laplace believed, and as is held by a good number of his still living followers.

We have even better reason for not falling into the exaggerations of that American philosopher who, in good faith, supposed that the Moon detached itself one fine day from the Earth, at a period when the latter was already completely formed.

"This enormous sphere rolling in space and illuminating the landscapes of our Earth, what is it in reality," he said recently, "but a fragment of our planet, that once filled the gap left on our maps by the great depression of the Pacific?"

Astronomy, being now really a science, cannot give its support to such fantastic theories.

When the ring, of which we have just traced the history, had concentrated into a single mass to form the Moon, the latter continued to revolve around us, and Newton was the first to show that in so doing it simply obeys the laws of gravitation. It is only in virtue of its first impulsive force that it does not fall directly towards the Earth. But let us suppose that force suddenly vanishes; immediately the light of our nights would, just like a mere stone, begin to move towards our globe, and would reach it in less than five days of twenty-four hours.

We have, for the sake of greater simplicity, assumed that the Moon goes round us in a circle. In reality, obeying the laws of motion discovered by Kepler, her orbit is slightly flattened in the form of an ellipse.

And the Earth not being situated in the centre of a circular orbit, it follows that the Moon is now a little nearer, now a little farther off.

At its mean distance it is only 238,833 miles distant. Its movement round the Earth is at the rate of a little more than a thousand yards a second,[1] but at the same time it shares in the movement of our globe round the Sun.

The figure which it describes in space is not then in reality a circle, or even an ellipse, but a curve that it is easier to represent than to define.

The perturbations in our own movement, which are caused by this ball of 2,160 miles in diameter, are beyond imagination.

At the time of Full Moon it diminishes the attraction of the Sun ; about New Moon, when it is passing between us and the Sun, its attraction unites with that of the latter in very slightly altering the shape of the Earth's orbit. If the Moon is behind the Earth in its path through space, it diminishes our velocity, whilst it accelerates it as it passes it front of us.

[1] The average velocity is 3,334 ft. per second.—*Translator's Note.*

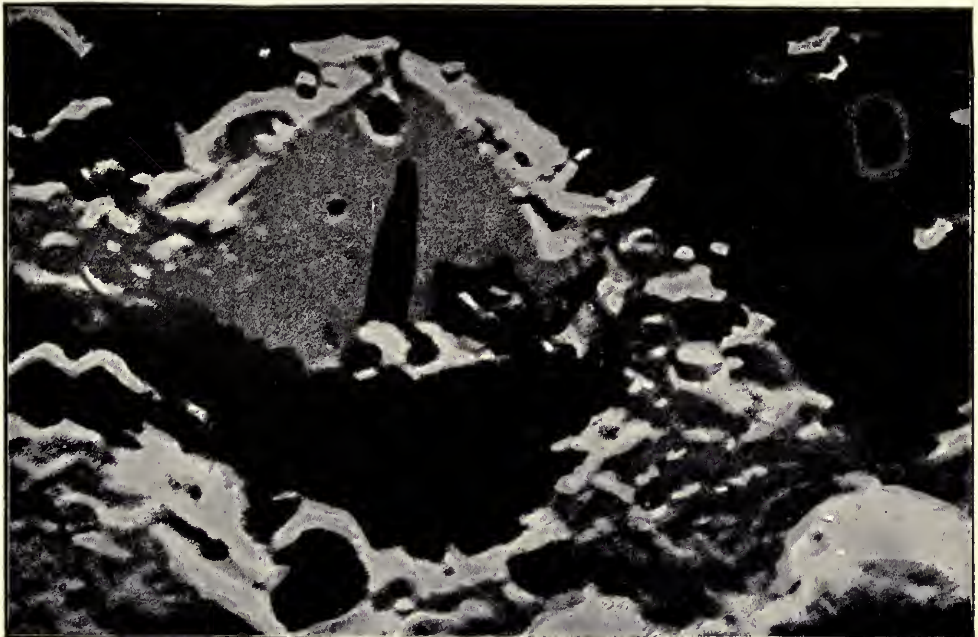
All this might very easily be reduced to calculation, but, alas! its orbit does not lie in the same plane as ours, and we have seen that the mean angle between the two planes is 5° 8′, and our having to speak of a "mean" inclination tells us that this also varies, so that altogether astronomers have no easy task in making their way through this labyrinth of masses, positions, distances, and the rest.

Add to this that the ideal ellipse traced out by the course of the Moon is itself deformed by the attraction of the Earth; that the flattening of its curve becomes more marked for a certain time, and then again diminishes, and you have a feeble idea of the Chinese puzzle the Moon inflicts on students of the mechanism of the heavens.

The period of its revolution—that is to say, the time it takes to come back to the same apparent point among the stars—is known to the hundredth of a second, but it also is variable.

Actually it is about 27 days, 7 hours, 43 minutes, 11·55 seconds.

During this time it appears to make a complete circuit of the heavens; it changes its place therefore each day to a very perceptible extent.



From a photograph taken at the Paris Observatory.

SUNRISE ON THE MOUNTAIN RING "WALTER."

(Note the long shadow of the central peak.

And, in fact, if on a fine night you note the apparent distance from the Moon to a star in its neighbourhood, you will see that at the end of a few hours there has been a considerable change of place. It amounts to a little more than 13° in the twenty-four hours, and this in the contrary direction to the movement of the celestial sphere.

It follows from this that each evening the Moon is about three-quarters of an hour behind its place of the evening before.

The solar day being itself a little variable, one can understand that it is impossible to base our calendar on the observation of the Moon.

We shall have occasion later on to return to some other points bearing on this matter, in order to complete our account of the movements of the Moon. For the moment we have something better to do. Do you see from the window the Full Moon rising slowly in the sky?

Let us go quickly up to our observatory.

The night is perfectly clear. The breeze ha fallen to a calm, and if there is no disturbance in the upper regions of the atmosphere the sight to be seen with the telescope will be wonderful.

However, we must not be in a hurry, but go to work in a systematic way.

Take first this opera-glass, which has a magnifying power of only three times.

Look through it; according to what we have already said, the disc of the Moon ought to appear to you to have a surface nine times greater than when seen with the naked eye. You see precisely what Galileo saw the first time he directed a telescope of this same power towards the Moon—that is to say, "precisely the same" so far as size goes, for in the year 1610 he did not first observe the Full Moon, but one of its phases.

At that moment certain details which now to you seem drowned in the solar light would be more marked, and so it was he compared them to the eyes of a peacock's tail, thus linking the graces of Diana and the charms of Juno's bird.

But what you can now see much more plainly than with the naked eye are the dark, irregularly distributed spots.

You no longer recognise the face you have been used to find there, and which the ancients saw there more than two thousand years ago, as is proved by these verses of Amyot, a translation from the Greek

DE RHEITA'S MAP OF THE MOON,
A.D. 1645.

of Plutarch, who himself was quoting the poet Agesianax :—

> "De feu luisant elle est environnée
> Tout à l'entour; la face enluminée
> D'une pucelle apparaist au milieu,
> De qui l'œil semble être plus rouge que bleu,
> La joue un peu du rouge colorée." [1]

All these sombre surfaces were a great puzzle to the old astronomers, who at last took them to be vast seas.

After all, it was not such a bad guess, and Père de Rheita gives us an explanation of it in a book he published at Antwerp in 1645.

"Not only," he says, "the aspect of the Full Moon is not different from that which the Earth presents when seen in very fine weather from the top of a high mountain, but it greatly resembles it. In fact, as one has often been able to verify by actual experience, the meadows and fields, the mountains and the valleys, illuminated by the light of the sun and bathed in it, are plainly visible from the summit of a mountain, while the waters, the lakes, rivers, and seas really look darker.

[1] "She is environed all round with gleaming fire; in the midst appears the illumined face of a maiden, whose eye seems to be red rather than blue, and her cheek slightly tinted with red."

"But if one were raised above the Earth a thousand, ten thousand, or twenty thousand leagues, or the whole distance that separates us from the Moon, and if one then observed the Earth with an excellent telescope, I have no doubt that it would appear to present a great resemblance to the face of the Moon."

It was therefore admitted at this period that the dark spots were seas, to which names were given; and although it is now proved that the Moon does not contain a single drop of water, astronomers have been so lazy, as to make no practical protest against this deplorable system of names.

Kepler and Scheiner indeed made maps of our satellite, but the first map worthy of the name was engraved by Michael Florentins van Langren, generally known by the name of Langrenus. This map was completed and published in 1645.

Its author was probably the first to apply the names of celebrated men to the features of the Moon.

At the same time Peyresc and Canon Gassendi of Digne also set to work on a complete map, but they abandoned their task when they heard that Hevelius had the same idea.

But put away your opera-glass, and be so good as to look through this telescope of moderate power, which magnifies thirty diameters. The fresh details you can now make out will give you an idea of the complex spectacle the disc of the Full Moon presented to the astronomers of 1650, when they made up their minds to set it down in a drawing.

The lunar mountains appearing in brilliant light; certain craters and circles showing their darker interior; whitish streaks radiating from the sides of some of them; and the greyish surface of the "seas"—which are nothing of the kind—all together present a variety of aspects that is somewhat confusing.

One would think it would have opened the eyes of the first selenographers to the real facts of the case.

Not at all. Hevelius did like his predecessors and even exaggerated their nomenclature.

This Hevelius, whose real name was Hovel, was a most enthusiastic student of the Moon.

He was born at Dantzig in 1611. His father, a rich brewer in that city, intended him for business, but Hevelius had other plans. When still young, he set off to London to complete his studies, and then he went to Paris, where he formed a friendship with Père Mersenne, Boulliaud, and Gassendi, then a professor at the Collège de France.

Till then he had been specially devoted to mathematics, but an eclipse of the Sun, which took place on June 1, 1631, keenly interested him in Astronomy.

Returning to his native city in 1634, he succeeded to the brewery, but his one real interest was the study of the Moon. The observations which he made at night he himself engraved on copper next day.

He thus obtained plates of singular beauty, which for more than a century were recognised as authoritative in the world of selenography.

When it came to giving names to the points shown on his chart he found himself in a difficulty.

He would have liked to place "up there" the names of famous men, but, as he himself tells us, he abandoned the idea, for fear of making enemies of those who were left out, or who might think their share too small.

He therefore decided to transfer to the Moon the names of our seas, cities, and mountains.

But of all this system of names, which was just as good as any other, and which was published after five years of arduous observation in his *Selenographia*, there remain now on our lunar maps out of 250 names only those of the Alps, the Apennines, and of four "promontories."

The Jesuit Riccioli of Bologna had not the same fears as Hevelius.

He knew men, and, making use of the observations of his colleague Grimaldi, he did not hesitate to place the names of learned men on the map of the Moon.

These, flattered in their self-love, were sure to buy copies, and this is how since 1651 the Moon has become the "cemetery of astronomers" and the "Pantheon of savants."

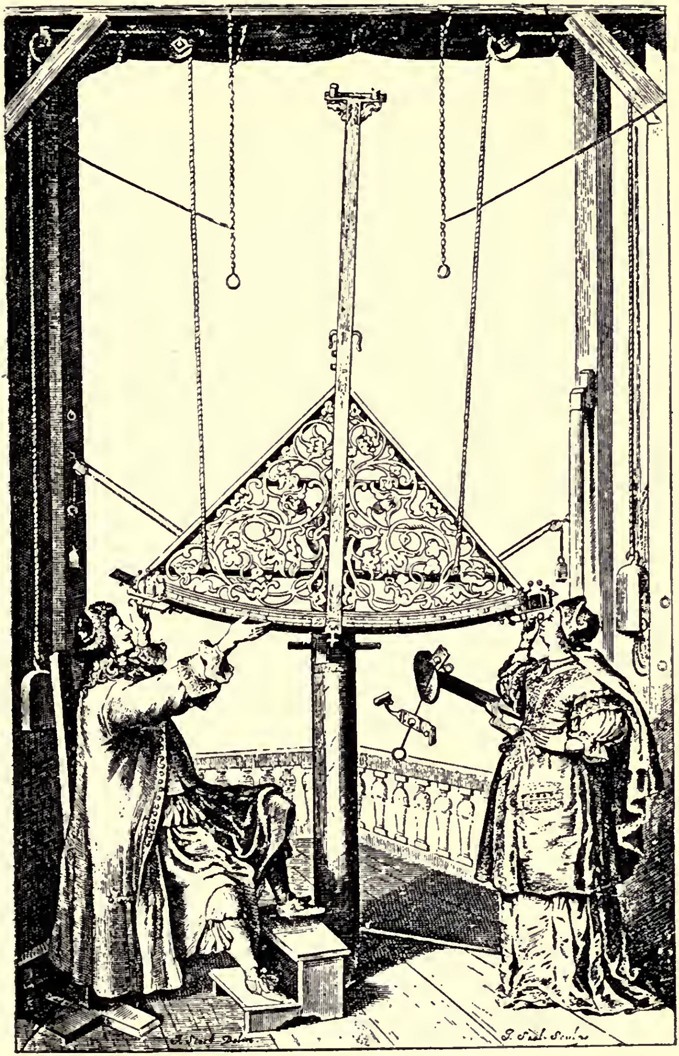
It is true that certain discontented spirits made some small protests, and accused Riccioli of having given more than their due share to his illustrious colleagues of the Society of Jesus; but the fear of being struck out of the list carried the day, and everyone was satisfied.

Besides, the learned of earlier days were not forgotten, and there were seen rising above the surface of the Moon famous craters and mountain-walled plains bearing the names of Archimedes, Plato, Aristarchus, Ptolemy, Copernicus, Tycho, Kepler, and the rest.

The names of the seas adopted by Hevelius, the Caspian, the Mediterranean, the Euxine, etc., were replaced by such names as the Sea of Storms, the Sea of Humours, of Rains, of Fecundity, of Cold, and other equally fanciful titles.

We must go on to 1680 before we find another interesting attempt to produce a map of the Moon. The Italian Domenico Cassini had received letters of naturalisation in France, and was the first director of the Observatory of Paris. Beginning in 1673, he arranged for drawings of the phases of the Moon to be made day after day by Patigny. For this work the artist made use of a large 34-feet telescope, which still exists.

The drawings were not published, but Cassini prepared from them a map, including also his own observations. It appeared in 1692, and the copper-plate was long kept at the Royal Printing Office; but one fine day the director of this State institution thought it was time to get rid of some of the material that was piled up in his storehouses, and the map of Cassini



Facsimile of an engraving in the " Machina Cœlestis."

HEVELIUS AND HIS WIFE OBSERVING THE POSITIONS OF THE HEAVENLY BODIES.

was included in a lot of copper-plates sold to a boiler-maker.

And it was a great pity, for though we still possess some reduced copies of this fine piece of work, not one example of the original has come down to us.

Arago, who tells the story, which he heard from Bouvard, adds rather naïvely, "This director was not, one may presume, a lover of Astronomy." We can well believe it.

Cassini's plate was rather more than a foot and a half in diameter. La Hire soon after undertook the production of a globe of the Moon, and then a map 4 metres in diameter, which was long displayed in a black frame on the staircase of the library of Sainte-Geneviève.

Then came (1762) the reduced map of Tobias Mayer (20 centimetres in diameter [1]), which remained the only exact one till 1824.

Sir William Herschel paid much attention to lunar studies, but he has left us no drawings of his observations. Nevertheless, he indirectly contributed to a deeper knowledge of our satellite, and this in a rather unexpected way.

[1] *I.e.* not quite 8 inches.

As he had concave mirrors for telescopes constructed by hundreds in order to choose the best of them for his own observations, and as at the same time the salary he received was insufficient for his expenses, he had the idea of selling to his brother astronomers the mirrors he did not use.

Soon he had a European fame as an optician. Everywhere his telescopes were appreciated at their true value, and for once the proverb which says that "Astronomy does not feed its adepts" was found to be incorrect.

The sale of his mirrors was for Herschel a source of almost unlimited profit.

The King of England ordered from him four telescopes of 10-feet focus. Herschel let him have them for £660—a mere nothing. The King of Spain was more generous, and paid him £3,150 for a telescope of 25-feet focal length. Two smaller instruments were bought by Lucien Bonaparte in 1814 at the price of £2,310.

The regular scale of prices began at £228 for a reflector of 7-feet focus, and went up to £2,600 for an instrument of 20 feet. The orders were numberless.

One might at first sight think that the distribu-


RING MOUNTAINS.
Plato D 1
Aristoteles G 1
Posidonius H 3
MOUNTAIN RANGES.
Appenines F 4
Caucasus
Alps
Taurus
CRATERS.
Aristarchus
Kepler
Copernicus
Proclus
SEAS.
Sea of Tempests
Showers B 2
Vapours F 5
Cold G 1
Serenity
Tranquility
Crises
SEAS.
Sea of Humors
Clouds
Nectar
RING MOUNTAINS.
Gassendi
MOUNTAIN RANGES.
Pyrenees
CRATERS.
Tycho

THE MOON.

tion throughout the learned world of these powerful telescopes, far superior to those that had been constructed before Herschel's time, would result in enormous progress in Astronomy.

But there was nothing of the kind ; and this once more proves the assertion that "The most essential part of an optical instrument is the eye that looks through the eye-piece."

To do useful work in Physical Astronomy, what is wanted is, in fact, the skilled eye guided by a brain. Hence the need of a long and patient training of the sense of sight, attentive and reasoning observation of the phenomena to which it is directed ; perfect sincerity, the entire abandonment of preconceived ideas—all united to a passionate love for science and truth.

The numerous possessors of Herschel's telescopes were doubtless lacking in the required qualities, for most of them made no new observation of any particular value.

Nevertheless, two of them, Schroeter and Pond, were exceptions, and thus the efforts of the celebrated Hanoverian astronomer in this direction were not useless.

Schroeter studied the Moon for many years, and published his interesting *Fragmenta Selenographica.*

"He was," says Goodacre, "a poor draughtsman, but, notwithstanding this defect, his sketches have considerable value."

At the beginning of the nineteenth century we find Lohrmann and Gruithuisen at work, but the latter was haunted by absurd ideas which he tried to set forth in his drawings. He was convinced that signs of life and civilisation were to be seen in the Moon.

It was then that Beer and Mädler showed by the colossal work which they brought to a successful completion what a student of the heavens can accomplish with the help of an instrument of very moderate power.

Their telescope had an aperture of not quite 4 inches; and, nevertheless, it was sufficient for them to accumulate on a map 90 centimetres[1] in diameter such a number of details that the other selenographers confessed they had not the courage to compete with them.

However, in 1864 the British Association formed a committee with the chief object of popularising the study of the Moon.

[1] 35·4 inches.

In 1874 Nasmyth and Carpenter published a magnificently illustrated volume representing the features of the Moon's surface from models made by the former of these observers.

From the artistic point of view no previous representation could give a better idea of what one sees in the telescope than those relief-pictures by Nasmyth.

Direct photographs are more exact, but they are far from having the charm of this work, which one never tires of examining.

Neison's book, published two years later, pays special attention to precision of detail, and adds several thousand new objects.

From this date we decidedly enter upon a new phase of Selenography. The work of Beer and Mädler is surpassed by these later productions, to which was added in 1878 the largest map yet published.

For thirty-five years Schmidt had been spending his time in studying and drawing the Moon. Making use of Lohrmann's measurements for the positions of the objects, he collected together the details contained in more than three thousand original drawings, in a large map 1·87 metres in diameter,[1] which was published by the Prussian Government.

Unfortunately, no second edition of this map was issued, and it is now not to be had. It contains no less than 32,856 "craters."

The British Association, when it founded its committee, proposed the publication of a map 5 metres in diameter.[2] But this ambitious project has not been carried out.

Though we have to do without this regular "ordnance map" of our satellite, we can meanwhile content ourselves with the works of Neison and Elger, the drawings of the French pasteur Gaudibert, and finally Goodacre's map, which measures nearly 2 metres[3] in diameter. The author has made use of the wonderful photographs obtained in America, and above all, those of the Observatory of Paris, to fix the form of the principal ranges and peaks, using special drawings for the minute details that are only to be seen with the most powerful instruments.

I suppose you would like to see these fine details with your eye at the eyepiece of a telescope.

[1] 73·62 inches, just over 6 feet.

[2] A little over 16 feet.

[3] About 6½ feet.

But you should know, my dear reader, that, for this, one must choose one's date; never make the experiment at the time of Full Moon, but on some evening about the First Quarter, for instance, at the moment when the Sun is just lighting up with his first rays the high summits of the lunar Alps and Apennines.

Oh! then I promise you a splendid sight, of which you can never tire.

No photograph, no drawing, can give a real idea of the sight of the Moon through a powerful telescope.

If we could accomplish this distant journey, we should make it at one of these exceptional moments, so as to be able to watch the sunrise and see the day-star rise slowly in the sky, lighting up step by step the towering peaks, and penetrating with its rays the hollows of the yawning craters and the black pits that are scattered over the surface of our satellite, while its cold light traces on the boundless plains shadows that stretch away beyond the reach of sight.

V

ON THE WAY

A WEEK has passed since the moment when the crescent of the New Moon first showed itself in the twilight. If we were of the Mohammedan religion we would be careful to note the exact hour of its appearance, which at certain periods of the year fixes the end of the fast of Ramadan.

Some days after we noticed the "earth-shine" on the moon, "the Old Moon in the arms of the New," to use a picturesque expression well-known to astronomers. Then, as the boundary between shadow and light advances little by little, a half of the disc of our satellite is at length illuminating with its uncertain radiance the landscapes of our Earth. Now is the favourable moment for making the long journey to which I have invited you.

But what about the means of making it? It is here the difficulty begins, and ancient and modern

Cyrano de Bergerac's Flight to the Moon
(From an old engraving).

romancers (including Cyrano de Bergerac) have invented only improbabilities.

Perhaps some centuries to come the problem will be solved, and solved in the simplest way in the world, so let us not worry about such a trifle.

Before the invention of balloons and aeroplanes no one thought seriously of being able to rise in the air.

Whoever finds out a means of suppressing or even diminishing the force of gravitation, that mysterious power which holds the heavenly bodies together and keeps us fixed to the earth, will thus enable men to leave their planet and launch out upon the conquest of neighbouring worlds. And the Moon will be the first stage of these interplanetary voyages.

I grant that it seems a daring supposition, but it is in no way an absurd one from the point of view of mechanics and physics.

But as to the physiological question—that is another matter.

The temperature of interplanetary space is near absolute zero—that is to say that during all its course a machine moving towards the Moon or a shell fired at that distant target would remain constantly at about 450 degrees (Fahrenheit) below zero.

Unless indeed radium or some similar substance should give us the means of bottling up heat, or that . . . .

But no ! Let us stop ! This is not a romance that we have to relate in detail. And at the present moment science need not trouble about your means of travelling to the Moon, and every day astronomers explore this distant region more easily than the pioneers of our globe explore the Antarctic.

The conditions of existence over there are as well known as those here on the Earth, and with one leap we can take the selenographers for our guides and come down into the middle of a lunar landscape, more easily than you go from London to Paris.

So we make our start.

At about six miles above the surface of the earth respiration becomes painful ; at about twelve miles the air is so rarefied that no animal "worthy of the name" could live there even for the briefest moment. Organic germs like bacteria and vibrios would, however, survive. Carried to those lofty regions by whirlwinds (which, by the way, are not very frequent events), they would come down again uninjured from their perilous ascent.

At 160 miles there is proof that there is still an atmosphere, but so attenuated, so slight, that it is almost an abuse of language to give the name to even the sum-total of the molecules to be found there.

At a little over 8,000 miles—that is to say, when we have traversed a distance about equal to the diameter of the earth—the great globe that we have left, seen from this distance, would occupy about 40 degrees of the heavens.

We pass the space of another terrestrial diameter; we continually increase our distance till it is three, four, five . . . nine diameters, the Earth steadily diminishing in apparent size. At ten times this distance it is still a magnificent object in the sky with an apparent diameter of more than 5 degrees, and with a hundred times a greater surface than that of the Full Moon seen from the Earth.

At the same time the size of our satellite is visibly increasing.

When we have arrived, what will be the apparent diameter of the Earth in the heavens?

Here is a problem in geometry that is easy enough to solve.

Let us suppose, first of all, that two astronomers are at two places the distance between which is just equal to the radius (half-diameter) of the earth. This condition, moreover, is easy to realise, as you shall see for yourself.

If you want to divide a circle, representing the earth's circumference, into six exactly equal parts, all you need do is to take a compass opened out to the length of the radius, and starting from any point of the circumference, mark off in succession round the circle, six points each the length of the radius apart. The sixth will bring you back to your starting-point. Join all these points together and to the centre, and you will have six triangles, of which all the sides will be equal and therefore all the angles also equal to each other. Each angle at the centre is clearly equal to one-sixth of 360 degrees (the angular measurement of the whole circumference), and thus it will be 60 degrees exactly.

It follows that two observers placed 60 degrees apart on the Earth are separated, in a straight line, by a distance just equal to the Earth's radius.

In practice it will be understood that one can take into account the flattening of the Earth's shape, and even make the observations from any two points of which the position is exactly known, the rest being only a matter of calculation and the principle being the same.

Let us suppose, then, our two astronomers are posted at the ends of a line equal to the radius of the Earth. You will grant that it will be easy for each of them, just at the same moment, to direct his instrument at the centre of the Moon and measure the angle at the base of the long triangle thus formed, the base being the line between them on the Earth, and the sides the lines joining each observer to the centre of the Moon, the line of sight of the observation.

Very well. But now our problem is solved, for every one knows that if one adds together the three angles of a triangle the total is 180 degrees.

Let us take an example. Our two astronomers have obtained for their base angles, one 100°, the other 79°.

$100 + 79 = 179$; and 179° taken from $180° =$ 1 degree. The angle at the summit of the long triangle would in this case have exactly the value of *one* degree.

Well, this experiment has been made in several different ways, and astronomers have always found a value nearly equal to *one* degree, or exactly 57 minutes and 2 seconds.

As early as the beginning of the eighteenth century Baron Krosigk spent considerable sums in determining, by the method we have outlined, the distance of the Moon from the Earth.

It was he who first had the idea of choosing the Cape of Good Hope and the city of Berlin as the bases of operations.

These two points of observation are situated just over 86 degrees of latitude apart, and nearly on the same meridian. It was perfect.

It was therefore decided that William Wagner should remain in Europe, while Peter Kolbe went to the Cape. Unfortunately, the former of these two observers did his part of the business very badly, and the affair had to be put off to a later occasion.

In 1751 the Paris Academy of Sciences took up the project again. The Abbé Lacaille was sent to the Cape, and Lalande to Berlin. This time the operation was completely successful. It was the first serious determination of the distance between the Earth and our satellite. Man had at last made the first step in the conquest of the heavens.

We may be allowed to go a little farther into this matter, which, though it is really so simple, is often misunderstood even by educated persons.

Let us return to the problem we have already discussed. From the solution we gather that an observer placed in the Moon would see the radius of the Earth under an angle of 57 minutes. Our planet would of course appear to him under double this angle, for as two radii equal one diameter, we have $57' \times 2 = 114$ minutes—or, what comes to the same thing, $1° 54'$.

Now, as many times as the angle $1° 54'$ is contained in 360 degrees, so many times could a Selenite place Earths, one touching the other, round a whole circumference of the sky.

Let us work out the calculation this time. It will only take a moment. 360 degrees, or 21,600 minutes, divided by 114 minutes (or $1° 54'$) will give us the figure 189.

If we suppose the orbit of the Moon to be exactly circular, it will therefore be equal to 189 times the diameter of the Earth at the equator.

The radius of this orbit, or the distance of the Earth from the Moon, will now be obtained easily by dividing this value by twice 3·1416,[1] or 6·28 in round numbers.

Now, 189 divided by 6·28 = 30, nearly exactly.

From which we must conclude that the distance to the Moon could be filled up with only thirty Earths.

Taking the equatorial diameter of our Earth according to recent measurements as 7,926·6 miles, we have for the approximate distance 237,798 miles.

To simplify our calculation we have left certain figures out of account. Bringing into our reckoning the latest valuations, and not neglecting tenths of a second, we get for the measurement 238,833 miles.

Even the error of a second would not make a difference of 28 leagues in the result. One can see very well by this example the precision obtained by the methods of modern Astronomy. We actually know the distance of our satellite to within a few miles.

To determine the size of the Moon is now mere child's play. It is easy for us to measure the apparent angular diameter of the Moon. It is just over 31 minutes.

At the same distance the Earth would appear

[1] Non-mathematical readers may be reminded that 3·1416 is the value of the circumference of a circle whose diameter is 1.—*Translator's Note.*

From a drawing by the Abbé Moreux.

Comparative Size of the Earth and the Moon.

about four times larger, for we have found its diameter to be 114 minutes.

Taking the diameter of the Earth as the starting-point, work it out by the Rule of Three, and you will find for that of the Moon about 2,155 miles, which will give you its volume as 49 times smaller than that of our globe.

It remains to determine the mass and weight of the Moon, but this question would take some time, and we shall soon have occasion to refer to it again.

Besides, during this long talk we have made serious progress towards our satellite.

A distance of 238,833 miles to traverse: but that is not a very great affair—only 30 times the diameter of the terrestrial globe.

A country postman who makes a daily round of over 18 miles would walk in 35 years as far as the whole distance between Earth and Moon.

Our express engine-drivers have to their credit much longer totals of travel.

An aviator who has any respect for himself easily does 100 kilometres[1] an hour. At this rate, and supposing he could keep up the same speed, he would reach the Moon after a flight of 160 days.

[1] 62½ miles.

On the day when men have at their disposal an explosive powerful enough to give to a shell an initial velocity of 12 kilometres[2] per second, the shell shot into the air would never come back to Earth. The so-called *civilised* nations could then find in the exercise of "shooting the Moon" a strong counter-attraction to the folly of mutually bombarding each other. Under such conditions the shots sent from the Earth might serve as mail-coaches, and take letters to our brethren the Selenites in less than a working day of twelve hours.

A despatch handed in at the central office of the Paris-Moon post at 6 a.m. would reach our satellite at 3 in the afternoon of the same day . . . always provided the State did not lay hands on the monopoly of the new line.

The slightest delay would have the most disastrous results. The Moon would have passed on, and the mail, finding no one to receive it, would carry on its despatches to "an unknown destination."

But the best way to realise how near the Moon is to us is to compare the time taken by light to reach us from that suburb of the Earth, and that

[2] 7½ miles.

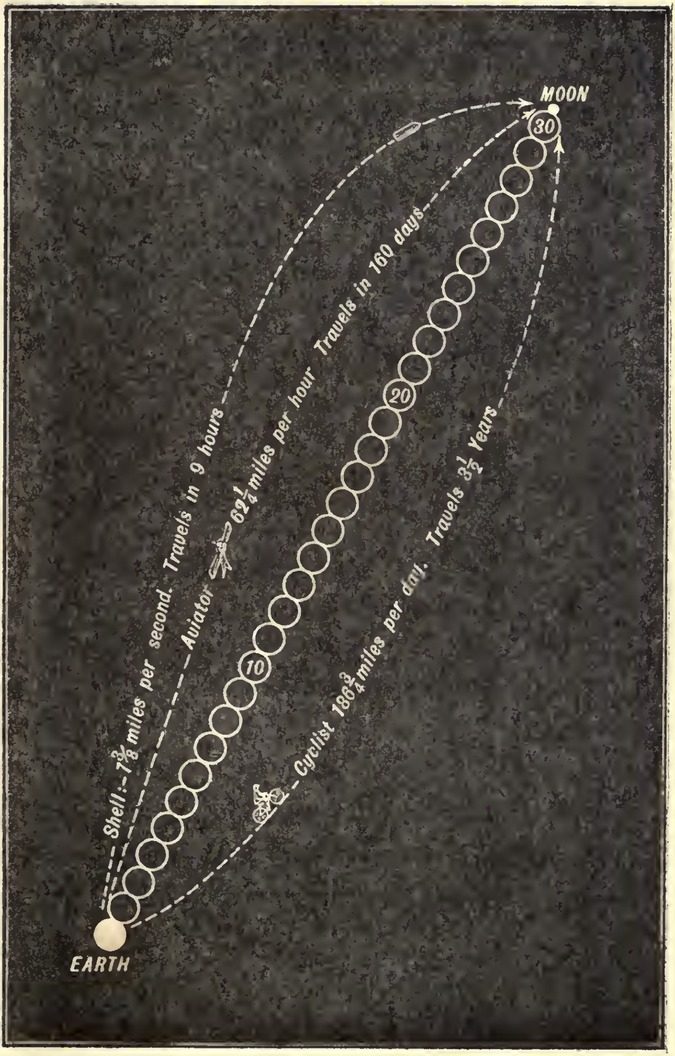


DIAGRAM ILLUSTRATING THE DISTANCE OF THE MOON FROM THE EARTH.

which it takes to pass across the spaces that separate us from the Sun, the planets, and, above all, the stars.

While a ray of light from the Pole Star reaches us after a long journey of 46 years, and takes more than four years to "work off" the tremendous distance that divides us from our neighbour Alpha Centauri, we know that the luminous vibrations from the Sun certainly do not take more than 9 minutes to arrive here.

Now, light, as you know, moves at the rate of 186,000 miles a second. In a little more than *one* second—say about the time it takes to count "two"—it crosses the abyss that separates us from the Moon.

This neighbouring globe, 49 times smaller than our own, is therefore really at arm's length. It moves in our wake, and shares, up to a certain point, our destiny in the universe. A politician might say that it is within our "sphere of influence"; and this nearness is enough to explain why astronomers in general study it so little, and yet know it so well.

But we have arrived. Our imaginary vehicle sets us down.

Let us open our eyes and lose nothing of the strange spectacle presented to our gaze.

VI

LUNAR LANDSCAPES

It is still night in the region in which we have landed on the surface of the Moon.

The sky sparkles with incomparable splendour. The eye can distinguish in it thousands and thousands of stars. Not even the glories of a tropical night can give any idea of what night on the Moon must be.

But soon the Sun will appear. There is no dawn to herald it, but already there is rising in the east a long, spindle-shaped trail of whiteness—it is the zodiacal light, ten times more brilliant than with us.

For hours this false dawn rises higher in the sky; its tints of phosphorescent colours are brighter and brighter from the summit to the base; in the midst of the enormous cone, all aglow with green and opal, there gleams a resplendent star: it is the beautiful Venus, hardly recognisable amid its mantle of light.

From a drawing by the Abbé Moreux.

A Gap in the Mountain Rampart of Copernicus.

But already the fine rays of the Sun's corona are heralding the day-star. For a few minutes the chromosphere is in sight, marking with a red glow the summits of the high mountain peaks.

Then all of a sudden blue rays of light, so strong that the eye cannot endure them, dart from the distant horizon. And now on all sides isles of brightness seem to rise up around us as the summits catch the sunlight. The day has come.

Where have we landed ?

Let us look attentively at our surroundings. Here aerial perspective is unknown, and the isles of light seem to mark out a large ellipse on the background of a black expanse.

Evidently we are looking down on the summits of a vast circuit of heights, nearly hexagonal, if we may judge by the arrangement of the outstanding spots of brightness. We are watching the dawn of the lunar day from the lofty rampart of a "crater" known as Copernicus.

"What ! Do you mean to say this enormous circle of fifty miles in diameter could be the crater of a volcano ?" Well, this clearly goes beyond all probability, but the old astronomers did not look at things quite so closely.

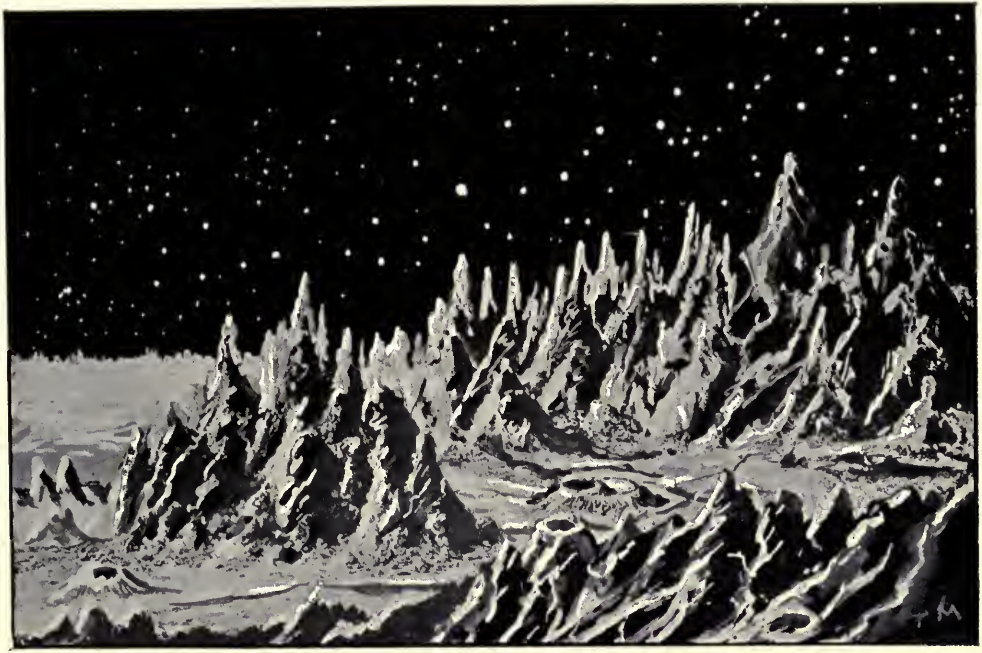
So long as there was a roughly circular rampart, generally resembling in appearance our terrestrial volcanoes, the comparison was inevitable; and as it is natural for the human mind to assign a cause to the effects it observes without waiting long over it, an explanation was soon found for those huge mountain systems, of which the smallest telescope will show you specimens by hundreds.

Provide yourself with higher powers, and you will soon remark that a good many of these lunar "craters" have a central mountain inside of them.

This peculiarity did not escape the notice of the first selenographers, and here is how they reasoned with regard to it:

We know by calculation that the intensity of gravitation is about six times less on the Moon than it is with us. Let us suppose, which is indeed quite likely, that the explosive effects of interior gases are as violent there as on the Earth. It follows that volcanic débris would be thrown six times farther. The central mountain was thus originally the active cone of the volcano, and everything is explained.

Thus, when the course of ages had not yet thickened the surface crust, and when the liquid or



From a drawing by the Abbé Moreux.

OUTLYING BUTTRESSES OF THE LUNAR ALPS.

molten interior communicated with the outside by the blow-holes of the central fire, these eruptive openings vomited into space and to prodigious heights the inner substances of the Moon. Rocks, volcanic matter of all kinds, vitrified minerals, dust and hot ashes—all this came from the underlying beds through the central vent, and was deposited in a huge circle at a greater or less distance from the volcano.

That there are in the Moon some small craters formed in this way seems beyond doubt, but the volcanic theory of the lunar circles does not explain everything.

One might, first of all, object that it is very strange that we generally do not find in the interior of these great circles any serious inequalities of the ground, any mountain resembling those of the outer rampart. One would expect to find regular concentric rings at various distances from the centre, marking the progressive decrease of the eruptive phenomena in the course of geological time.

But there is nothing of the kind! And, what is still more to the purpose, the central peak has not often a form reminding us of the mouths of our volcanoes.

And then, who can believe that this elevation in the interior, always of lower height than the mountains around it, could have thrown out masses of matter to such a distance that they are piled up into these enormous circular ramparts, the height of which often exceeds that of the loftiest summits of the Alps?

And an example of this is before our eyes. Copernicus is the monarch of the ring-shaped mountains of our satellite, the king of the *ringed plains*, to use a favourite expression of English selenographers, an expression greatly to be preferred to the old grotesque and fanciful terminology of the "craters."

There are more than twenty-five miles between us and its centre, as we stand perched on a point of its rampart towering some 13,000 feet above its interior plain.

Including its external slopes, the diameter of this circular mountain is nearly sixty miles. From one side of Copernicus to the other there is about the same distance as from Paris to Orleans.[1]

An attentive observer might pass all his life in studying Copernicus. He would every day find

[1] Or from London to Portsmouth.—*Translator's Note.*

new details in it, and this marvellous object includes all the interesting characteristics of the other mountain rings, several of which, however, exceed it in extent.

Petavius, for example, measures 100 miles from one side to the other, and Manginus and Lagrange show the same dimensions. Herschel presents a diameter of 90 miles; Gauss is still larger—110 miles; Humboldt is 112½ miles across, and Clavius exceeds this width by more than 11 miles.

And then there are the giant circles of Grimaldi, Stoefler and Maurolycus, of which the mean diameter reaches 150 miles.

If one could transfer Maurolycus to France, placing its centre at Orleans, the circular ramparts that form its boundary would pass near Le Mans, Tours, Nevers, and Saint-Denis. Paris, Melun, Sens, La Charité, Bourges, Blois, and Chartres would be hidden away in its interior.[1]

A strange kind of crater indeed, the bottom of which is so very like the great plains of the Beauce and the Sologne, where one might walk for hours and hours without seeing any mountain on the horizon.

[1] It may help the English reader to note that similarly if the centre of Maurolycus were placed at Oxford, its rampart of mountains would run in a huge circle which to the north-west would lie just beyond Wolverhampton and the Potteries, and would sweep round by Burton-on-Trent to Peterborough, pass a few miles east of Cambridge and through Chelmsford, cross the Thames below London, about Gravesend, pass through Ashdown Forest, in Kent, and reach the sea at Littlehampton; then pass through the middle of the Isle of Wight, reach the mainland again near Christchurch, take in the whole of Salisbury Plain, and by the Mendip Hills reach the shore of the Bristol Channel opposite Newport, and then curve through the south-east borders of Wales and back to the Pottery district. Among the places within its mountain ring would be London, Birmingham, Bristol, Southampton, and Portsmouth.—*Translator's Note.*

Through their having failed to make any exact measurement of these enormous formations, the old astronomers allowed themselves to be misled by appearances.

But while we are making these explanations the Sun has entirely risen. On our earth in latitudes about half-way between Pole and Equator, the time the Sun takes to show his complete disc, from the appearance of its upper margin till its lower edge just touches the horizon, is only $2\frac{1}{4}$ minutes. On the Moon it takes no less than an hour for the same thing to take place . . . and you can see the reason of this.

Our satellite turns on its axis about 28 times less quickly than the Earth, and everything is in proportion to this slow rotation.

From the time of sunrise a period of 354 hours of light goes by, and then comes a night of equal duration.

Such is the length of the lunar days. It has always seemed to me an excellent illustration of the relative nature of time.

Our divisions of it into hours, minutes, and seconds are obviously arbitrary, and based upon the return of the Sun to the same point in the heavens.

Now, this interval between two of its passages across the meridian depends on our movement of rotation. And just as we do not think of basing our measures of time and our calendar on the rotation and revolution of Jupiter, so the Selenites would have no reason for founding theirs on our terrestrial calendar.

Thus, when I promised to let you pass a day on the Moon, I meant to speak of a true lunar day, so we have more than three hundred hours before us, in which to visit our satellite and carry out excursions that a terrestrial explorer might envy.

It is not, however, the fact that days as long as this are entirely unknown in our world. Our polar regions give us some that last even longer, but the Sun of these far northern lands is a smoky torch compared to that which shines like an electric arc light in the lunar skies.

You can see for yourself that, though the Sun is hardly risen above the horizon, you can already distinguish all the details of this fantastic natural scenery that seems created for Titans.

Now we notice the five central mountains of the great ring, imposing masses whose summits gleam with a harsh glare, while their bases are still plunged in the shadows of a night that is never absolutely black but is illuminated by the earth-shine.

Over there, on the horizon, are the glittering higher summits of the opposite rampart, and the loftiest of them rears its terminal cone to the height of more than 13,000 feet—I nearly said "into the air."

But here we have to change our terminology and our literary phrases. The absence of air, or of any gas that can be breathed, completely alters our way of looking at things.

On the Moon there is no aerial perspective. Everything glitters with dazzling light. Its rays strike on the projecting rocks with an absence of all gradation that gives them an unreal look. Things near and far seem confusingly alike, and the eye is not guided in its judgment of distance by any variation of tint.

The clouds which temper the effect of the sun-light, which rise from the valleys, assume definite shapes, float hither and thither in the ocean of air carrying with them the dreams of poetic souls, and which shroud the mountain crests and give variations of dull grey or bright colour to the sky—all this is unknown in the lunar landscape. And this only half-surprises us, for as soon as ever we reach the Moon we recognise that air and water are alike unknown to the lands on which we have set foot.

But the first selenographers were far from suspecting this. Otherwise they would not have given to these vast desolate plains such ill-chosen names as "sea," "ocean," and "marsh."

The stony desert in front of us out of which Copernicus rises is known as the "Ocean of Storms."[1] We shall traverse the extremity of it, its borders, as we continue our journey northwards.

The absence of any atmosphere—a fact definitely established by modern astronomers—explains another very characteristic peculiarity of this world that is so unlike our own.

On the Earth the Sun's rays reach us after a long passage through the layers of the atmosphere. There is thus what we may call a selective absorption of some of them, a winnowing out, so to say, of the different colour rays, many of which are lost in the meshes of this new kind of sieve.

The shortest light-waves, those of violet and

[1] Oceanus Procellarum.

Copernicus.

blue, are delayed on the way, and only the longer radiations near the red end of the spectrum reach us easily.

Do you want a palpable proof of this? Watch the sunrise and notice the general tone of the landscape up to midday.

At dawn the east is bright with the rosy tint of which the poets sing. The clouds are edged with lines of scarlet. All white surfaces reflect the same colours. Then the day-star appears and the red is mingled with other parts of the spectrum, giving at first violet tints and later on more yellow tones.

As the rays of the sun rising above the horizon pass through a less dense body of air, the shorter light-waves reach us more easily, and it is towards midday that we receive the most of them.

At that time of day, especially in tropical countries, the shadows of things assume quite plainly the complementary tints of these rays.

Such of my readers as live in Algeria or Tunisia, or in Egypt or India, can see this for themselves with the help of a photographic apparatus. Let them look at the image of a landscape on the dull surface of the focussing glass, and they will see that the shadows are all quite blue.

On the Moon, where there is not even the slightest trace of an atmosphere, the Sun's rays do not pass through any filtering screen before reaching the ground, and it is this blue colour that gives its dominant note to the landscape. And this is why the Sun seen thence looks like an electric arc, a gigantic lamp of glittering blue ; a gleaming mass whose fierce blinding light adds all the more to the impression of coldness produced by the sight of a world rigid in death—unreal and yet existing, gloomy yet full of light, blue and black at the same time.

Nevertheless if we look more closely we shall find there, as on the Earth, a whole scale of colours. In the midst of this mountain-ring now partly bathed in the Sun's rays, besides the dominant note of blue, and half drowned in it, you can make out the various shades of minerals and rocks like those of our Earth.

And here we may remark how little is the worth of the assertions made by certain astronomers who repeat the follies of their predecessors, and tell us that on the Moon there is no medium, that everything is either black or full of light, accordingly as the Sun is absent or darts its rays upon it.

No! Objects on the Moon must keep their own colours, tinged with blue of course, for that is the general tone of the sunlight on these wild landscapes. The angle of the precipices on which it falls, the slopes of the ground, the height of the Sun—all these causes combine to produce half-tints, diversified tones, and changing effects as on the Earth.

During the night on the hemisphere of the Moon that is constantly turned towards us, our planet serves as a moon to its satellite—an enormous disc reflecting a light fourteen times more intense than that with which fair Diana's orb illuminates our landscapes, even when at the full and at its maximum brightness it passes through the zenith and sends down its soft light into the smallest clefts of our deep valleys.

When the "Full Earth" sends back to the Moon the reflection of the sunlight and our own atmosphere adds to the effect of this fierce glare, it is like broad day on the surface of our satellite. The intense shadows of the mountains are less dark, and absolute blackness can find a refuge only in the deepest chasms.

Even in the midst of the long lunar day Sun and Earth act as allies and combine their light to soften the crudity of tones and colours.

This is a point that we, men of the Earth, had not till now realised, but which our first excursion shows us in the clearest fashion.

And nevertheless there can be no possible comparison with the landscapes of the Earth. Cast your eyes over and beyond these frightful precipices, those steep declivities broken only by two or three terrace-like slopes of débris, and what presents itself to your dazzled eyes is above all a spectacle of the most awful desolation. There is not a patch of moss, not a heath-grown ledge, to soften the rocky ridges and sharp-cut edges of these abrupt surfaces; not even the lowest form of plant-life, not a lichen, to attenuate the wild aspect of the landscape and give it even the slightest appearance of life.

And now we can better understand that passage in which Nasmyth, most enthusiastic of selenographers, tells us how the whole landscape as far as the eye can reach is the realisation of a dream of the most awful desolation and of nature without life. It is not even a dream of death, but it is the vision of a world where life has never existed.

And yet who can assert that in the far-off times of the Earth's first ages the Moon was not the abode of living beings?

If we had at our disposal the "time machine" of Mr. H. G. Wells, the romancer who deals in the most astounding of improbabilities, we might witness a spectacle of much the same kind . . . while looking at our Earth.

One or two turns of a crank and the flywheel of the machine begins to revolve.

Ten million years have passed by with the speed of lightning; twenty millions; fifty; eighty; a hundred million years.

Let us stop the machine and take a look.

In the sky the day-star has become pale. The last fires of our glorious Sun are burning down.

Its ruddy rays still reach the Earth, but alas! it is only to light up the most mournful of pictures.

The Earth's atmosphere exists no longer. The rocks and minerals and calcareous compounds have absorbed it little by little. The waters of the oceans have permeated the underlying strata, and the cold of interplanetary space has frozen up the last traces of moisture. On the desert ground no crop any longer ripens. The Earth has become sterile. Forests and prairies have all disappeared.

At the beginning of this slow but continuous cooling down of the earth the human race in a body had taken refuge in the equatorial zone, where a dwarfed vegetation had replaced the abundant flora of the tropics.

Some millions of years more and only a vegetation like that of the polar regions could withstand the glacial climate.

One by one most species of animals became extinct. To hold out somewhat longer the last families of the human race dug into shafts and deep-lying underground tunnels, and it is there that in the last of these catacombs their frozen bones are now lying.

Ten million years more and an explorer traversing this silent desolation might well believe he had good reason to think of the Earth as Nasmyth does of the Moon.

Every trace of organic life would, in fact, have disappeared. Our monuments, our powerful machines, all the products of our industry and civilisation, would have been reduced to dust and gone back to the earth, and not one particle would remain to reveal the previous existence of life on our planet.

Such an end of the Earth and its inhabitants is the normal manner of death for the worlds in stellar space. But poor humanity may vanish hence in some frightful catastrophe, and science, even in the guise of the Wells machine, is powerless to reveal to us the lot that awaits us.

However this may be, this account of the end of our planet seems to apply very well to the lunar world. Our satellite is 49 times smaller than the Earth. It has therefore cooled down more quickly; and though its days are materially longer, the phases of its life among the heavenly bodies have been hurried through more rapidly than ours.

At the present time there is nothing to justify us in believing that life exists on the surface of the Moon, and the astronomers of our Earth have explored every corner of it.

The smallest angular space that the human eye can appreciate is about half a minute. A magnifying power of 30 diameters enables us to see a spot a second in diameter. Now an angular distance of a second on the Moon represents about 1,960 yards. This is the limit of visibility for small telescopes. But when one adapts to a more powerful instrument a magnifier of 300 diameters, the eye can distinguish details measuring only 197 yards. With the power of 600 one can perceive an object measuring 98½ yards. This would be reduced to 59 yards and 29½ yards if we used powers of 1,000 and 2,000 diameters.

In practice we have unfortunately to reckon with an element of some importance, the atmospheric waves, of which our telescopes also magnify the effects in the most distressing fashion. The training of the observer, the practice of the eye, and the diameter of the objective have also to be taken into account. There has often been talk of powers of 2,000 being adapted to large telescopes. But in the opinion of *all* selenographers these high powers give no result when applied to the study of the Moon, and as a rule we have to content ourselves with a magnifying power of 400.

But here another question arises, and we must beware of falling into the mistake of certain popular astronomers who reproduce an argument of Arago.

This astronomer tried to make out that to magnify a portion of the Moon's surface 2,000 times was the same thing as to bring it 2,000 times nearer, and *consequently* to see it just as we see an object on earth 120 miles distant from us —in the same way, for instance, as a tourist sees the mountains of Corsica from the heights above Monaco (distance, 190 kilometres = 118½ miles.)

Well, this reasoning loses all its force as soon as we try to apply it to an object in the heavens elevated above the horizon and anywhere near the zenith.

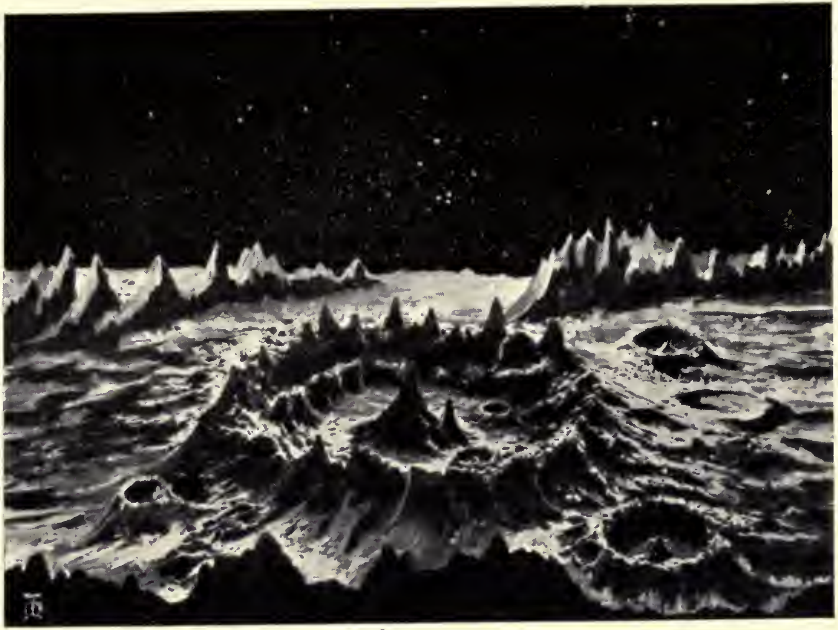
In this case, as a matter of fact, our line of sight passes through a depth of air equivalent only to that which separates us from an object placed at a distance of about 6 miles on the earth, whilst when we look at Corsica from Monaco or the cone of Etna from Malta the rays of light come to us weakened by passing through a mass of air that is twenty times denser. This more or less opaque screen, agitated by strong currents, in continual movement and laden with dust and vapour, deadens the tints and blots out the details so that the comparison is worthless.

What should be said is that with a magnifying power of 400—and experience is there to prove it—a trained eye can distinguish on the Moon an object 135 metres (or 443 feet) in diameter, and this magnifying power is ordinarily used by astronomers.

In exceptional cases—with an abnormally clear and calm atmosphere—we can use powers of 600 and observe on the Moon spots and objects only 90 metres (= 295 feet) in diameter, whilst, according to Dr. Weineck, in the case of our photographic maps of the Moon we have to be content with making out spots of 700 metres (= 2,296 feet) in diameter.

The superiority of telescopic vision over photography is still more marked when it is a matter of revealing a long narrow object such as a geological fault or a crack in the ground. With a magnifying power of 400 we can distinguish clefts in the surface that are only 40 to 50 metres wide (*i.e.* 131 to 164 feet).

A great building like one of our cathedrals, a railway-station, a village, a regiment on the march, would therefore be quite visible. But no one has ever observed such signs of civilisation. We are, however, thus in a good position for studying the question of changes in the surface formation of the Moon, and astronomers have not failed to do this. . . . But time is running on, and this question will come up naturally in the course of our intended excursions.



From a drawing by the Abbé Moreux.

PERSPECTIVE VIEW OF A LUNAR MOUNTAIN-RING.

VII

ON THE MOON

But we must see about leaving this elevated point of observation overlooking the mountain crests of this circle of Copernicus, and making our way down to visit the great plains that the sunlight is now bathing in its slanting rays.

It is not easy to fix upon the line of easiest descent. Everywhere the mountain sides go down abruptly at a startling angle of inclination, then rising up to minor outlying summits they join on to subsidiary ranges or folds of the surface that are arranged round Copernicus like the spokes of an enormous wheel.

We cannot dream of reaching the region to the south, of which you can distinguish the deep gorges and frightful precipices where the rocks fall noiselessly and the avalanches of stones awake no echo.

Let us rather make our way to the north side; the ground there looks more practicable.

But take note of this—you will recollect that the lunar globe has an attraction six times less than that of our terrestrial globe. Here is the explanation of that sense of lightness which is so thoroughly characteristic of the place.

Have you ever thought about the cause of weight? It is essentially only a variety of attraction. It seems that the fall of an apple was enough to start a train of thought that put the great mathematician and philosopher Newton on the track of the discovery that the heavenly bodies attract each other in the same way that the Earth draws falling bodies to its surface. Later on he was enabled by a study of the movement of the Moon in its orbit definitely to establish those great laws of attraction which are the basis of the mechanism of the heavens. "Things work out," said Newton, "as though bodies attracted each other according to their mass, that is to say, according to the quantity of matter they contain."

The weight of a body is not therefore an inherent quality of matter.

Let us, for instance, imagine a single atom existing by itself in the world and in space. There is nothing that attracts this atom. Therefore it has no weight. Place in its presence a small mass of other atoms. Immediately the two unequal masses tend to approach each other, and weight comes into existence.

This attracting force of weight is therefore in the highest degree something variable according to the masses of bodies. The mass of the Moon being much less than that of the terrestrial globe, one can very easily see that a stone transferred to our satellite would there be less strongly attracted, and would therefore weigh less.

Take, for instance, a rock which you would judge to weigh exactly 100 pounds here on the earth. Lift it in your arms on the Moon, and you would feel as if you were holding up barely 20 pounds.

And, wonderful to say, there was no need for astronomers to make an excursion to the Moon in order to determine the weight of bodies on its surface and even to weigh the Moon itself. There are plenty of ways of doing this, and the most simple to grasp is one that can be easily understood by everybody.

If the Moon were as heavy as the Earth, the two bodies would equally attract each other, and both would begin to revolve round their common centre of gravity, that is to say, round a point situated just half-way between the Earth and the Moon.

But as a matter of fact their masses are unequal, and at the moment when the Moon is before the Earth on its orbit it is easy to discover by observation that we are drawn forward just a little by our satellite. The amount of this displacement, calculated by the apparent displacement of the Sun in the heavens, is about 2,300 miles, or nearly the eighty-first part of our distance from the Moon. Hence it can be inferred that the mass of the Earth is 81 times greater than that of the Moon ; at any rate, it is most certainly something between the numbers 80 and 83.

Let us follow out the consequences of this line of reasoning. Newton has shown under his second law that attraction diminishes in proportion to distance. We can show this even here on our Earth where bodies weigh less the farther they are from its centre.[1] If, then, the Earth and the Moon were the same size, a stone on our satellite would weigh 81 times less than here on earth. But this

[1] Such experiments are of course made not by balancing weight against weight in scales, but by the use of spring balances.—*Translator's Note.*

Region of the Lunar Apennines.

The diagonal range is that of the Apennines; the great mountain ring in the lower part of the photo is "Archimedes."

conclusion does not hold good as matters actually are, for the stone on the Moon is much nearer its attracting centre. The figure just given is therefore far from expressing the reality, and making all necessary calculations, as we know the radius (or semi-diameter) of the Moon, we find that the force of gravity, or weight, on our satellite is only *one-sixth* of the average of that same force at the surface of the Earth.

And there is another consequence—if you weigh here on the Moon what would be 60 pounds with us, a spring balance would indicate only a weight of 10 pounds, and as your muscular force remains the same as ever, you now understand how here you can succeed in easily lifting an enormous block of stone.

In the same way, before jumping over an obstacle, or leaping across a mass of sloping débris or an open crevasse, you will do well to be careful, and to remind yourself that an effort which would enable you "in your own country" to make a jump of 6 feet would carry you to a distance of 36 feet on the surface of the Moon.

But if we take certain precautions this diminution of weight is just what will give us an unexpected means of reaching without difficulty the base of this tremendous declivity, and rapidly making our way to the outlying hill-buttresses of the great chain of the lunar Apennines.

Isolated peaks rearing their crests above a vast desert, numbers of great tumuli in the summits of which open yawning craters whose depth the eye cannot fathom, low hills, parallel furrows, some basin-shaped hollows, and here and there enormous crevasses—such is the appearance of the wide tract that we traverse to the north of Copernicus in order to reach the great "Sea of Rains" (the *Mare Imbrium*).

We might thus make a march of hundreds of miles always in the midst of this desert-like steppe with its overheated surface burned up by the blaze of an unendurably tropic sun.

At the lunar noon—that is to say, when the Sun has completed half its course across the sky—the ground will be heated to such a degree that it would immediately roast any organic substance placed upon its surface. The temperature would be above 212 degrees, and during the long lunar night of about two weeks a gas thermometer would indicate a cold of some 300 degrees below zero.

Region of the "Mare Serenitatis."

The great plain is the so-called "Sea of Serenity." The isolated crater in its upper part is "Bessel." The large crater near the end of the range forming its upper boundary is "Plinius."

What plants, what animals could survive such extremes and such variations of temperature?

But already the Apennines are in sight. For 400 miles this mountain range, the most beautiful in our satellite, will close in our horizon to the eastward.

It has, however, no resemblance to the mountain masses of our own Alps. Here we have a titanic piling up of rocky material, heaped together with a breadth that in some places is as much as 160 miles, especially where the chain appproaches the "Sea of Vapours."

From this shapeless mass there rise up slender peaks of which you can see the long shadows on our right, forests of rocky steeples, columns, minarets, gigantic obelisks, crowding together their impossible-looking shapes to form a panorama that seems something unreal, masses of dazzling blue on a black background all spangled with stars.

Behind us the great mountain ring of Eratosthenes stands out strongly from the monotonous plain that marks the beginning of the "Sea of Rains."

Let us press on continually to the northwards. We salute as we pass it by the square-shaped mass of the Wolf Mountains, of which the loftiest summit reaches a height of 12,000 feet, and Mount Huyghens with its tall peak, whose summit goes up to an altitude of 18,000 feet.

Now in front of us and a little to our left, an enormous mass rises—the mountain ring of Archimedes, the interior diameter of which is not less than 50 miles. We are now in the "Marsh of Fogs." Cast a glance as we pass by at Theatetus, the little volcano near which certain astronomers think they have made out a trail of smoke. We have now reached the first buttresses of the lunar Alps. Once more we see great peaks rising before us, but they are less numerous than those in the Apennine chain, where selenographers have counted up more than 3,000.

Here the eye distinguishes only some hundreds, of which the most remarkable is "Mont Blanc," with its height of nearly 12,000 feet.

At the base of its precipitous sides a wide valley opens out, a fantastic gap stretching away in a straight line as far as the eye can reach, a giant furrow that underground forces have formed in the midst of this impenetrable scene of mountain chaos.

Not far from here rises the huge circle of Plato, a vast arena 60 miles across.

But the hours are going by, and the Sun is inclining towards the west. Let us hasten our steps towards the "Sea of Serenity," and continue our excursion so as to reach the southern part of the Moon.

We are now nearing Linnée, a small crater which for years has been raising amongst astronomers the question of changes in the Moon.

Linnée was very closely observed by earlier selenographers. Now modern descriptions do not at all correspond to those given by Lohrmann, Schroeter, Huggins, and several others.

It would seem that in the first half of the nineteenth century important changes took place in the appearance of this curious object, and that in 1866 its interior was filled up with some kind of white matter, very likely lava.

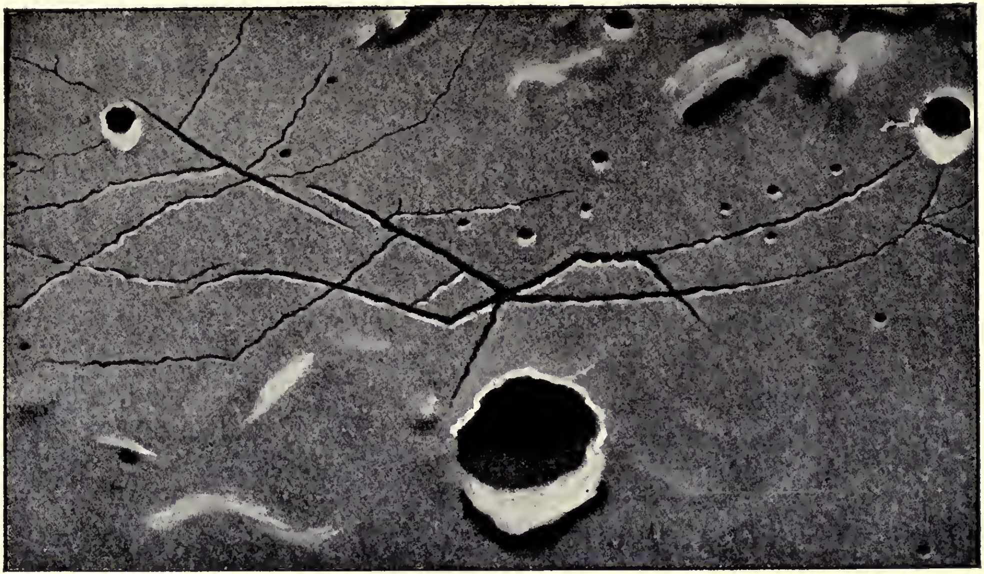
The two little craters of Messier show also very curious changes of appearance; now they are visible, now they are hidden by a screen that looks like smoke.

We may also take note of the observations of MM. Charbonneaux and Millochau, who remarked similar appearances—whitish patches some 4 miles long, showing themselves over a little crater situated near Theatetus, which we remarked as we passed by it.

The study of all these facts, and of a number of others which have not been so fully investigated, raises therefore once more the problem of the internal activity of a central fire in our satellite. It is very difficult to admit the possibility of the presence in the Moon of appearances due to any vegetation surviving even on the low-lying plains, but we have yet to find some explanation for certain changes of colour that recur with each lunation, and for a number of variations that fit in very well with the supposition that internal forces are still reshaping the topography of the Moon's surface.

Besides, the geology of this land so near our own is well calculated to puzzle even the most learned. The surface crust of our satellite has been subjected to the action of powerful forces that have no analogy with those which appear to have determined the surface features of our Earth.

It is probable that at the outset—that is to say, at the period when the Moon was in a viscous



From a photograph by Krieger.

EXAMPLE OF THE CREVASSING OF A HARD SURFACE—CLEFTS NEAR TRIESNECKER.

state—the gases imprisoned in the interior of its mass raised here and there enormous domes, a kind of gigantic bubble, thus leading up to the falling in of the surface on a vast scale and in circular or elliptic shapes.

This would be the origin of such great depressions as the "Sea of Crises," the "Sea of Serenity," the "Sea of Rains," etc. All these are in fact bounded by mountain masses, of which the steepest side is always turned to the part that has fallen in.

Later on, as the crust gradually became thicker, these swellings of the surface were localised within narrower limits; the consequent collapse of the surface resulting in the formation of mountain rings like Tycho, Ptolemy, Theophilus, etc. . . . The presence of central mountains in these rings is also fairly well explained by this theory—for want of room certain parts of the falling dome were forced to pile themselves up one on the other.

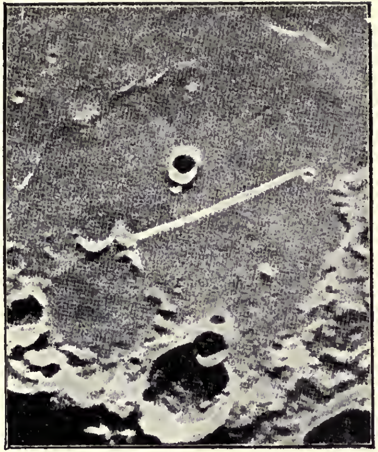
In some cases the rise of floods of lava has more or less filled up the inner arena, and overflowed in metallic streams through gaps in the encircling walls.

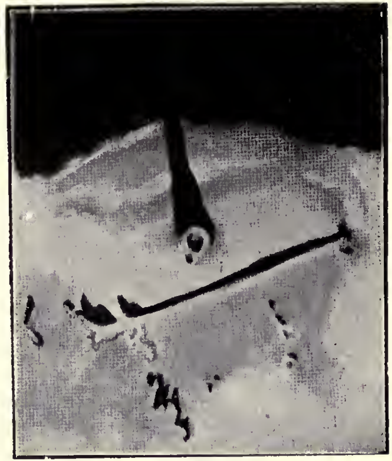
Finally, when the outer crust could no longer, on account of its want of elasticity, bend to the upward force of the interior gases, the envelope cracked and split around the points of pressure, and we might thus account for those broad rays that seem to radiate from certain mountain rings, such as those of Tycho, Kepler, and Copernicus. Sometimes the breaks resulting from this upward pressure from within have formed long yawning chasms, as in the neighbourhood of Triesnecker or Hyginus ; sometimes they have been filled up by metallic lavas, as in the case of the rays around Tycho, where we see them glittering more and more brightly as the Sun rises higher above the horizon.

The southern part of the Moon—that which we see at the top in an astronomical telescope which reverses the object—is not at all like the regions we have just visited.

To get an idea of it, let us rise above the surface of the Moon and continue our journey so as to have a bird's-eye view—from an aeroplane, if you like.

Your first impression at the sight of this wild landscape will make you think of a huge volcanic region, but as you look more closely you will soon find out your mistake.





Drawn by the Abbé Moreux from a photograph taken at the Paris Observatory.

THE "STRAIGHT RANGE" PRESENTING THE APPEARANCE OF A SWORD.

The real lunar volcanoes are hardly visible with our most powerful telescopes.

The great circles displayed before your eyes are all vast plains surrounded by mountain ramparts.

First of all there are Hipparchus and Ptolemy, measuring about 125 miles in diameter. Their inner arena is full of eruptive mouths that we cannot count. Broad valleys open to the south of Ptolemy, towards Alphonso and Arzachel, and there is nothing on earth that can give us an idea of such a confused mountain upheaval. Peaks of 6,500, 10,000, 13,000 feet overhang yawning hollows 12 miles across; volcanic cones have risen by hundreds on the bare abrupt slopes; then over vast extents of ground the crust has fallen, producing gigantic cracks as in that region of the "Sea of Mists,"[1] where the arena of an old mountain ring is split in two.

A good half of it has sunk down, and the two edges of the "fault" have actually a difference of level amounting to 2,300 or 2,600 feet; this is the "Straight Range" to be seen near "Birt," and which in certain lights takes the form of a sword.

[1] The *Mare Vaporum.*

Farther south the elevations become still higher in the direction of Tycho and Maginus.

Then there is Clavius, with its boldly shaped rampart, a deep cavity overhung by mountains more than 16,000 feet high, with a vast arena 142 miles in diameter.

Behind us Maurolycus and Stoefler, already shrouded in night, show only the shining tips of their fantastic summits.

But the south pole of the Moon has a greater surprise in store for us. Against the dark sky there stands out a gigantic mountain chain, higher in proportion than our Himalayas, for the Leibnitz Mountains probably rise above the level of 25,000 feet. Beside these lunar giants the Doerfel Mountains show up their imposing masses, amongst which Schroeter and Mädler have measured summits 26,000 feet high.

Here the eye of the astronomer can go no farther. The Moon, as we have seen, always presents the same side to the Earth. What kind is the other side? It is a mystery. And no human being will ever be able to solve it. Certain learned men of the past tried to make out that, as a result of the Earth's attraction, the Moon must have

From a drawing by the Abbé Moreux.

ASPECT OF THE "MURUS RECTUS" (THE "STRAIGHT RANGE") OF THE MOON.

 A nearly vertical escarpment some 2,500 feet high running along the line of a gigantic "fault."

taken an irregular form, that of an egg, of which the longer end is turned towards us.

On the other hand, it has been an easy matter for us to assure ourselves of the absence of any atmosphere on the visible part of the Moon. We know that every ray of light is bent by refraction in passing through the layers of our atmosphere, and this is why the Sun is visible a little before its time of rising and a little after its setting.

In the same way, in the case of an "occultation," when the Moon passes between us and a star, if there were refraction—and therefore a lunar atmosphere—the star would not disappear at the exact moment given by calculation, and the time it was hidden from us would be shortened.

Well, on this point observation has never been in disagreement with theory, and so the partisans of a lunar atmosphere, obliged to abandon this point, have not quite given up the game as lost. "If the Moon," they say, "is more elongated on our side of it, the opposite side is nearer the centre, therefore lower, and it is precisely in that region the air has accumulated."

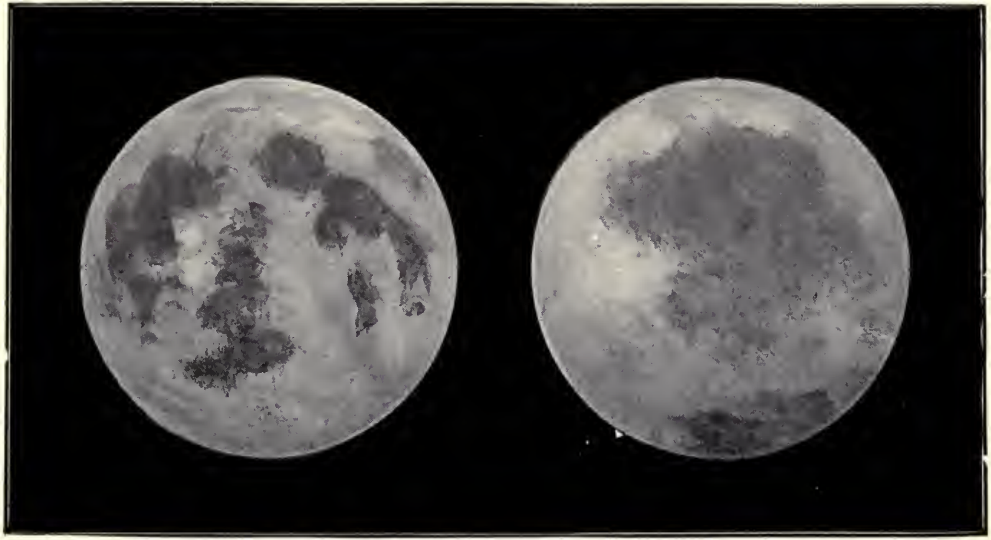
Unfortunately for them, measurements taken from contour lines drawn for the Moon by Dr. Franz have not confirmed this way of looking at the matter. The Moon is indeed a practically spherical body. The most one can grant is that subsidences of the crust—which, however, are of no great importance—have taken place there as on the Earth. These are the result of a law which we shall study in a future volume—a law that points to the opposite side of the Moon roughly resembling the drawing we give here.

However, it is not quite strictly correct to say that we can see only one side of the Moon.

Our satellite indeed completes its movement of rotation and revolution in the same time, but the orbit it follows is an ellipse.

When the Moon has gone through a quarter of its orbital movement it has revolved a little more than a quarter on its own axis. An astronomer on the Earth therefore sees in each lunation a border or lateral segment that he would never have a sight of if the Moon described an exact circle in its movement round the Earth.

Thanks to this phenomenon of *libration* (as it is called), the Moon seems to possess a sort of swaying movement, in consequence of which we know a little more than the half of its surface.



Conjectural Formation of the Unseen Side of the Moon (Right),
On the supposition that elevations on the visible disc (left) correspond to depressions on the opposite side, as is the case with our Earth.

Similar phenomena, due to other causes, allow us to get sight of a narrow border at the north and south. Well, all we thus get a glimpse of points to the supposition that the other side of the Moon has a similar constitution to that which we see.

But it is time to return to the Earth, which we can see all this time high in the sky. The Sun is already setting, and its last blue margin will soon disappear below the horizon. The lengthening shadows already warn us of the approach of the lunar night. The cold begins to assail us. Let us fly from those endless plains, those monstrous peaks, those countries of death and desolation, those silent landscapes, those frightful solitudes, those black tomb-like chasms, those granite precipices, those awful summits where no gust of wind any longer goes by, those slender spires of rock whose balance there is no longer anything to alter, those deserts that life has quitted for ever ; let us fly from this region of eternal silence, with its apocalyptic visions and its sepulchres that the angel of death has closed with his icy wings.

VIII

THE MOON, THE TIDES, AND THE CHANGES OF THE WEATHER

We have seen in the preceding chapters that the Moon attracts the Earth, just as the latter exerts an attraction on its satellite. The intensity is obviously not the same, seeing that their masses are in the proportion of 1 to 81·5.

This attraction of the Moon influences also terrestrial objects, and this is easy to understand. If you strew iron filings on the surface of a magnet, the particles will attach themselves to the magnetised metal; and if you bring another powerful magnet near it, you understand quite well that the action of this second magnet has the effect of diminishing the attraction of the first for the filings.

When, for instance, the Moon passes between the Sun and the Earth, it must add its effect to that of the Sun, and terrestrial objects must be attracted to some small extent by the mass of the

From a drawing by the Abbé Moreux.

DIAGRAM TO ILLUSTRATE THE ACTION OF THE MOON ON THE TIDES.

two globes, but above all by that of the Moon, which is much the nearer.

Very delicate observations are required to measure this diminution in the intensity of gravitation or weight, but nevertheless the phenomenon takes forms that render measurement easy when we consider it in the total effect of the action it exercises on the oceans that envelop the Earth. It causes a periodical rise in them, which we know by the name of the *tide*.

Every time, in fact, that the Moon passes over a region of our globe, the particles of water, being less attracted by the Earth, are raised towards the Moon, the whole mass moving towards the precise point where the attraction of the Moon is strongest, and the phenomenon changing its place according to the course of our satellite and its progress in the heavens.

At first sight it is more difficult to understand why this kind of swelling of the ocean, this rising up of the waters under the Moon, should take place also in the opposite region of the Earth—that is to say, at the Antipodes. And nevertheless, theoretically it must be so.

At the antipodes of the place at which the Moon is on the meridian, all the particles of the ocean that are situated farther from our satellite than the centre of the Earth are subjected to a weaker attraction. They have thus less tendency to draw nearer to the Moon, and consequently they rather tend to a delay in moving towards it ; there should therefore be a high tide.

If this explanation seems to you difficult to grasp, take at least this much of it : Every molecule of water situated on the farther side of the Earth as regards the Moon, by this fact is subject to a minimum attraction on the part of the Moon ; therefore, on the part of the Earth farthest from the Moon the liquid element is less heavy than in the regions at both sides of it. Now, physical science demonstrates that if one puts liquids of different density into the two branches of a tube bent into the form of the letter U, in order to be at equilibrium the less heavy liquid must stand at a higher level. And this is precisely what happens in the ocean on the opposite side from the Moon.

This simple explanation, however, was not known to the ancients. It would, indeed, have been enough for them to have remarked that the phenomenon of the tides has an evident connection with the passage of the Moon across the meridian, for the tide, like the Moon in the sky, is about three-quarters of an hour later each day.

It is, however, true that, though there are two periods of ebb and flow in a day, the moment of high water does not actually occur till after the passage of the Moon across the meridian of the place, and one must take into account the position of the points of observation and the configuration of the coast.

It was Kepler who first suspected the true cause of the tide and attributed it to the action of the Moon; but it was the fate of this remarkable genius that his theories had no chance of success in his lifetime.

In 1631 one of his contemporaries in connection with this very subject called him a visionary, and as his opponent was a scientific man—I was going to say an official one—poor Kepler could only bow his head.

And all the same, he who thus took to task the illustrious Kepler was not exactly a partisan of Aristotelian philosophy; he was always claiming for himself the right of freedom of thought, and if I did not tell you his name you would be quite unable to guess it.

This learned man had already shown himself much the weaker of the two in a discussion on physics with Torricelli, and his name was . . . Galileo!

As the Moon has an action upon the oceans—that is to say, on the liquid envelope of the globe—one might expect *a priori* that in studying the general laws of our atmosphere we would find in it a tide somewhat similar to that to which the liquid mass is subject.

It is an interesting problem, because it might lead us to practical results from the meteorological point of view.

With the idea that a tide in the atmosphere could not take place without causing widespread disturbances, more than one builder of theories has already suggested a possible relation between the phases of the Moon and the changes of the weather.

Simple in appearance as the problem is, it is nevertheless one of the most complex that men of science have had to solve. So they have attacked it from several different sides at once.

Photo taken at the Paris Observatory.

REGION OF THE "MARE VAPORUM."

At the base of the photograph is the Mare Vaporum; above this is seen Triesnecker with its long clefts or crevasses. The great mountain ring at the top and to the right is Ptolemy, 117 miles in diameter.

In some countries experience has shown that there is more rain during the time the Moon is increasing than when it is waning. This is clearly the case in the north of France and Germany, and our meteorological records supply good evidence of this fact.

However, we must not exaggerate the importance of the relation between the number of rainy days of the first period and those of the second ; the difference is extremely slight.

But in the south of France this law does not hold good : it is even reversed.

And besides, theoretically it is easy to fix by calculation the amount of this lunar tide of the atmosphere. It works out in tenths of millimetres at its maximum, and thus comes within the range of mere errors of observation ; that is to say, it does not appreciably affect our barometers.

The explanation is perhaps to be sought elsewhere.

We know that the variations of the barometer, especially notable falls of it, are not essentially connected with changes of weather.

France and Western Europe are in a somewhat exceptional position for profiting by the indications of the barometer.

The southern regions are much less subject to the influences of the Gulf Stream than those of the north, and conditions such as bring rainy weather in one place do not produce the same effect in other districts.

Is there any meteorologist of to-day who can flatter himself that he knows thoroughly the conditions that bring rain?

It may very well be that the Moon by its presence above the horizon has some connection with rainfall through chemical action, electric action, or the effect of ionisation, and through slight mechanical action.

It is therefore most prudent to hesitate before making any pronouncement, and it is, above all, our duty not to deny the facts under the pretext that we cannot see any explanation for them.

Here, as elsewhere, it may be that popular belief knows better than the men of science.

Moveover, there is something to be said for the truth of the theory from another point of view. In recent years mathematicians have approached the question by another way, that seems likely to give more results.

We have already noted that the Moon is not always at the same distance from the equator of the heavens. Its movements, considered in relation with the plane of the elliptic, to which the Earth's axis is inclined, give rise to a phenomenon that everybody can observe for himself.

There are times when it passes the meridian at a great height in the sky, tracing a very large arc of a circle above the horizon. At others, on the contrary, it remains confined to the regions towards the south, does not rise high, and sends us its rays very obliquely.

So the depth of atmosphere on which it exerts its action is continually varying. Our satellite thus produces displacements of the air, a kind of enormous swelling outwards, that passes slowly from the tropical regions to higher latitudes.

This is what calculation proves. What has observation to tell us on the subject?

Exactly the same thing. The limit of the region of the trade winds is subject to a periodical movement backwards and forwards corresponding to the declination of the Moon. This movement, or rather this swaying of the zones of high and low pressures, which is radically linked with a unique phenomenon, may therefore bring fine weather and rain simultaneously but in different regions.

The combination of this effect with the Full Moon or the New Moon is perhaps in more than one instance an additional element in modifying the weather, so that, all things considered, I do not despair of seeing men of science gradually coming to a proof of what all the world admitted long since, namely, that our satellite really counts for something in certain atmospheric changes.

But we must take care not to exaggerate or push things to extremes. The intermediate phases between Full Moon and New Moon do not seem to be so chargeable with the bad results popularly attributed to them.

"But," you say, "what about the 'Rust Moon'?"

Patience! We are coming to that.

First of all, do you know the meaning of the word? and at what period the Rust Moon appears?[1]

Towards the end of April, or rather during the

[1] The popular belief which the author here discusses is common among the French peasantry, but does not seem to be current among country folk in England.—*Translator's Note.*

month of May, when the temperature of the day begins to increase perceptibly, and thus conditions are favourable for the rising of sap in plants, a somewhat curious phenomenon occurs every year.

Put out a minimum thermometer a little above the ground, and you will find that even during nights in which the indicator has not gone down to freezing-point some plants have been frost-bitten, and the affected buds are a sort of rust colour. Now, this occurs always under a clear, cloudless sky. If the Moon is above the horizon, it is of course quite visible; hence the accusation brought against it by the peasants of "rusting" the plants.

The "Rust Moon" has been known from time immemorial. Market gardeners and vine growers are afraid of it, and they attribute its ravages to a special cold-producing power in the rays of our satellite. Let us see if there is any basis for this accusation. In any case the "Rust Moon" has been officially known to men of science only for a century, as is shown by this story related by Arago:

"'I am pleased to see you gathered around me,' said Louis XVIII one day to the members of a deputation of the Bureau des Longitudes, who had come to present to him their Almanac and Annual, 'for you will clearly explain to me what is the Rust Moon and how it acts upon the crops.'

"Laplace, to whom these words were specially addressed, seemed dumbfounded: though he had written so much about the Moon, he had in fact never dreamed of such a thing as the Rust Moon. He appealed with a look to all his colleagues, but as no one seemed inclined to speak, he decided to reply himself:

"'Sire, the Rust Moon has no place in astronomical theory. We are not in a position, therefore, to satisfy the curiosity of your Majesty.'

"That evening, when at the card-table, the King made very merry over the embarrassment into which he had thrown *his* Bureau of Longitudes. Laplace heard of it, and went to see Arago at the Observatory in order to ask him if he could throw any light on this famous 'Rust Moon' that had given rise to such a disagreeable incident. Arago knew no more about it than Laplace, but he promised the illustrious astronomer that he would make inquiries of the gardeners of the Jardin des Plantes and other horticulturists.

"As the result of his investigation, Arago settled

From a drawing by the Abbé Moreux.

INTERIOR OF A LUNAR VOLCANO.

that henceforth the 'Rust Moon' would be taken to be that which beginning in April reaches the Full either at the end of that month or oftener in the course of the month of May."

I do not know if the definition is perfect. It has often given rise to excited discussions, which however seem to me very puerile.

The gardeners settle it each year in their own way. Sometimes their plants are touched by the frost, sometimes they don't do very badly, and the "Rust Moon" does not always "rust" them. But however this may be, we have here the popular account of a fact that we may look into more closely.

Agriculturists, as we have said, assert that at night with a clear sky leaves and buds exposed to the moonlight are "rusted," in other words are frost-bitten, although the thermometer exposed to the air remains several degrees above freezing-point. On the other hand, if, as the result of the presence of clouds in the sky, the rays of the Moon do not reach the plants, these effects are not observed, although the general temperature of the air remains the same.

It would seem then, at first sight, that the lunar rays are the cause of this chilling.

Nevertheless, if at the time of New Moon, when our satellite is not above the horizon, the sky clears, you will find that the young shoots, especially those of the vine, freeze and "rust" just the same.

The Moon has therefore nothing to do with the matter, and the explanation of it must be looked for elsewhere.

The cold of the night was specially studied long ago by Wilson, and here is what that physicist observed in 1783:

After having placed a thermometer on the snow and noted that it indicated about 22° below zero, while the temperature shown by another 4 feet from the ground was −14°, he saw the lower thermometer suddenly rise some 8° as clouds came over the sky.

When the night is fine and clear, therefore, bodies lose their heat by the simple process of radiation. The presence of a screen or cloud, or a covering of canvas or of straw, slight though it may be, at once neutralises this effect.

All our readers can easily repeat Wilson's experiments. They will find that in still, cloudless nights the grass has always a *lower* temperature than the air six feet above it. We must not, therefore, judge of the cold that affects a plant during the night merely by the readings of a thermometer hanging in the air.

This phenomenon is perfectly well known, and has been taken advantage of from time immemorial—in India, for instance—for making ice. Shallow vessels filled with water are arranged in an excavation filled with maize straw. A bank of earth runs round it to keep the cooled air from disturbance. When the sky is clear and the air calm without too much humidity, and the temperature falls below 50°, the water freezes, even when a thermometer laid on the straw indicates 40°. One hears of ice-makers who employ in this way hundreds of workmen, and the process was used for the same purpose by the physicist Wells, who repeated the experiment in England during the summer.

But to succeed one must have a clear night; in cloudy weather there is no radiation, and the difference of temperature becomes imperceptible.

Now, all this helps us to understand what happens at the time of the "Rust Moon." In the nights of April and May the temperature of the air is often not more than 8° to 9° above freezing-point.

Then, as the result of nocturnal radiation, the ground may cool down to one or more degrees below freezing-point. The plants are subjected to the same cooling process, and are frost-bitten. Now when this takes place, it is under a clear sky, and if the Moon is above the horizon it shines in all its splendour. If, on the contrary, the weather is cloudy, the Moon will not be visible, and there will be no frost on the ground—unless, of course, the general temperature of the air falls below freezing-point.

It is therefore true, as the gardeners assert, that with the same general conditions of temperature, a plant may be frozen or not frozen according as the Moon is visible or hidden behind the clouds. But once more, the moonlight is here only an indication of the fact that the sky is clear, and it is on account of this clear sky that the night cools down ; but this freezing takes place just the same when the Moon is not above the horizon. We may say, then, with Arago : "The observation of the gardeners was therefore incomplete, but it would be wrong to make out that it was false."

And now may we ask why these nightly frosts take place in spring, at the end of April and the beginning of May, and not in summer or autumn?

The first reason is, that at that time of the year winter is hardly ended, and the Sun has not had the time to warm the Earth, whilst later on, the loss of heat by cooling down in the night does not equal the excess of heat stored up during the day.

To this chief reason another must be added. We know what an important part water, in a vaporised state, plays in maintaining and equalising the temperature of our atmosphere. Well, the quantity of this vapour is always varying, and we have proof of this every day in the changing indications of the hygrometer.

Since the invention of that instrument physicists and meteorologists have studied its tabulated results, and this is what they find.

The total amount of vapour in the air increases constantly from spring till the month of August, usually the hottest time of the year. But from September it decreases, and reaches its minimum precisely in the month of April, the very time when it is most necessary for counterbalancing nocturnal radiation.

So in spring everything combines to give us chilly nights and to make the Moon fall under the suspicion of having a cooling effect, of which it is quite innocent.

But does this mean that the Moon has no effect on plants?

It would be very rash to make such a statement after merely examining the theory of the "Rust Moon."

We must look at the problem from another point of view, and this is what we are going to do.

From a drawing by the Abbé Moreux.

A CLEFT IN THE MOON'S SURFACE NEAR HYGINUS.

IX

THE MOON, VEGETATION, AND ORGANIC LIFE

THE question of the influence of the Moon on plants is as old as the world, and about every twenty-five years we find some bold spirit who does not disdain to break a lance in its defence.

In a little book on Meteorology that is very popular in the province of Berry, M. Larchevêque writes that, according to his investigations, there is among the people of central France a very strong belief in the influence of the Moon on planting, sowing, etc. For instance, it is held that one should plant and sow and prune trees at the New Moon. The first growth from the seed and the subsequent progress of the plant will be more rapid and vigorous if these operations are carried out at the New Moon.

This is the theory. From inquiries I have made in a good many places I find that it may be taken to be a very widespread opinion. One comes across it in much the same form in all the countries of the world.

But—and this is the main point of the matter—this same theory has been knocked to pieces by a fair number of men of science, and the popular exponents of learning have boldly taken up the cry.

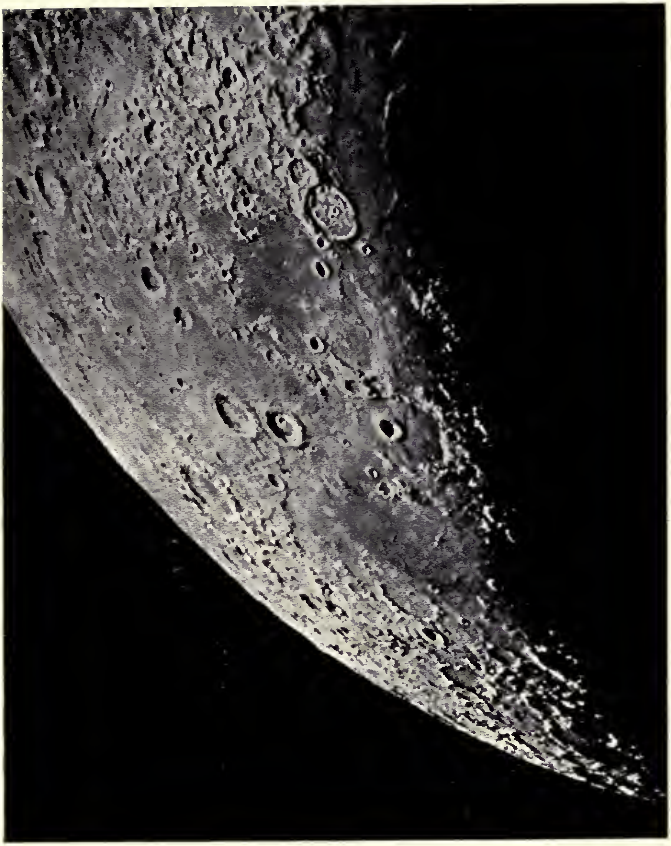
"These are," they say, "nothing but old women's stories, to which we need pay no attention."

Have you remarked that often the savants are just those who know Nature the least?

I have met with mathematicians who could hardly distinguish a maize plant from a leek; physicists ignorant of the most elementary principles of physiology; and geologists who, on the other hand, had not opened a book on physics for twenty years.

This exaggerated specialism, with its disregard for all that is outside its scope, produces the most deplorable results.

Men of science who boast, as they have a right to do, of the experimental method, and sometimes practise it, are too often mere "men of the laboratory," and lose sight of Nature.



From the Lunar Atlas of Lœwy and Puiseux.

NORTHERN HORN OF THE MOON.

(Reversed image.)

Astronomers in general treat with contempt any possible influence of the Moon on vegetation, and the meteorologists do much the same.

If the explanation of a fact is not available, men refuse to accept it as authentic. The whole history of science supplies us with many instances of this.

Remember how the Academicians of a former day denied that stones could fall from the sky; denied the facts of somnambulism and hypnosis at a time when these phenomena were not accurately studied; denied the very real fact of lightning coming down in the form of a ball of fire, etc.

It seems to me that there is something of the same kind going on with regard to the Moon; instead of having recourse to the experimental method, people are content to deliver dissertations, and imitate the very methods of the Aristotelians and Scholastics that they rail at!

A series of scientific experiments might be carried out under due supervision, but I know of no astronomers or meteorologists who have "resigned themselves" to such labours in order to study the subject with which we are occupied.

Without taking one side or the other as to this alleged influence of the Moon, I thought the best plan would be to hear the evidence of the rival camps.

Let us listen first to M. Henri Ayme, the Secretary of the Agricultural Syndicate of Lagnes in the department of Vaucluse:

"I am not one of those who think that science has discovered everything, and that one should reject without examination whatever it cannot explain. But if something that cannot be explained is to be taken as certain, I consider that it ought to be supported by serious proofs from experience. So if I am convinced of the absence of any influence from the Moon in the region of vegetable physiology, this is not because such an influence would be inexplicable, but it is above all because during twenty-five years of agricultural practice I have never found any seriously established fact to support this belief, and because I can bring very precise facts against it.

"In our country the belief in the influence of the Moon is far from having the force of an axiom, witness the farmer who said to me:

"'We know the Moon can do nothing to our crops, but one hears it so much talked about that it always has some effect on the imagination.'

"The facts cited in support of it cannot be taken as indisputable. Let us see how this is.

"There is a widespread belief that trees pruned at the Old Moon grow less strongly than if the pruning is done during the New Moon; but at the same time, according to the popular belief, there is a day that is specially unlucky for such work. It is the last Wednesday of the lunar month; so it is an accepted idea that a tree cut on that day will not send out a new shoot, and this to such a point that one is recommended to choose the day for cutting away brambles and noxious plants. Here is what a farmer told me:

"'One year, being very pressed with work, I began to prune six young mulberry trees, without taking much thought about the day or the Moon. When I had pruned three of them it occurred to me that it was the last Wednesday of the Moon. I left my work unfinished, feeling quite sure that I had killed my three trees, and at the New Moon I came back to them and pruned the three remaining ones. But afterwards I could not see the least difference between those that ought to die, and those that, according to the popular belief, ought to grow vigorously.'

" 'That,' I replied, 'is an experience that ought really to make you lose all your wonderful confidence in the Moon.'

"And here are several other instances of which I have been a witness :

"One day we were busy planting potatoes. A neighbour passed by and addressed us thus :

" 'So you want to have a crop of little beads ?'

" 'How is that ?'

" 'The Moon is no good to-day for the work you are doing. You will have for your crop a lot of potatoes, but they will be very small ; the Moon has no force.'

"You see, he spoke very confidently. When we dug the potatoes there was nothing out of the way in their number, but they were of splendid size ; and this made us say that if the Moon had had all its force on the day we planted them, they would have been as big as pumpkins.

"One day I was engaged in grafting an apricot tree, when a professional grafter noticed what I was doing.

" 'What ! grafting to-day ! But the Moon ?'

" 'I must tell you I have not consulted her.'

"The professional, with a smile of pity for my ignorance, was so good as to say to me :

THE EDGE OF THE MOON LIGHTED UP BY THE SETTING SUN.

(Enlargement from a negative taken at the Paris Observatory.)

"'The graft will take, but the tree will not bear fruit—the Moon is New, but that is no good for grafting!'

"My graft was a success, and still better, the following year it gave me six fruits. Twenty years have gone by. In that time my apricot has become a fine tree, which has always been very fruitful, despite the prophecy that condemned it to sterility.

"As to wood being liable to be worm-eaten according to the state of the Moon when it is cut, I have no belief in it, for I have always had my woodcutting done during the wane of the Moon, and this has been no obstacle to the worms attacking it.

"As for the story of wood floating or going to the bottom of the water according as the Moon was Old or New when it was cut, this is the first time I have heard of it. I should like to witness the experiment, as to the success of which I have plenty of reasons for doubt.

"Many gardeners take no notice of the phases of the Moon. They are content to do their sowing at the most convenient times, and succeed just as well as those who consult the Moon on every occasion.

"I might quote many more examples to show that this belief in the influence of the Moon rests on no serious facts, that it is only a popular prejudice very difficult to uproot, and based on the agricultural knowledge, or rather ignorance, of two hundred years ago.

"I remember having read *La Maison rustique du XVII^e^ Siècle*, a big folio of 1,200 pages, in which this belief in the Moon has the place of honour, and is made to explain how to be successful, just as one explains a chess opening.

"At that time it was not only agriculture that was subject to the Moon, all knowledge was derived from the science of the stars. To give only one instance, doctors had a day of the Moon for giving medicine to, or bleeding, those of phlegmatic, sanguine, or hypochondriac temperaments.

"To-day medical science has got rid of these prejudices.

"Let us hope that, to its great advantage, agriculture will do the same."

So speaks M. Ayme.

Is it exactly "to the great advantage" of agriculture that it should deny the existence of any lunar influence on vegetation?

That is precisely the point of the difficulty, and we shall see other and as serious combatants entering into the debate on the opposite side.

In an extremely interesting paper written by a horticulturist, under the title of *Action vitale de la Lune*, M. Gallé-Defond (of Port-de-Piles, Vienne) has put together some notes that, to my mind, meet in very clear and precise language the objections above stated.

Here are the rules which he deduces from numerous experiments.

He first of all remarks that the New Moon appears to be favourable to the ascent of the sap in plants, which therefore grow more vigorously at this period of the lunar month.

From this he believes he can deduce different methods of treatment for various kinds of plants, according to the results he wishes to obtain.

In the case of carrots, radishes, salsifies, turnips, leeks, and beet, all belonging to the class of plants cultivated for their roots, the sowing should be done from the 5th to the 15th day of the lunation.

But aubergines, chervil, chicory, cabbages, lettuces, onions, parsley, tomatoes, haricots, green peas, etc., and finally cucurbitaceous plants, melons and cucumbers, should be sown and planted during the period of the waning Moon.

According to this observer, the cucurbitaceous plants in particular have been the subject of conclusive experiments.

All this goes to confirm the old saying: "If the Moon is lost the beans are spoilt."

Popular wisdom would thus have some good in it.

It will be seen that here there is no question of sowing on a Wednesday rather than any other day; one must not exaggerate anything.

If the Moon exerts any influence on vegetation it would therefore be by being favourable to the rise of the sap during the first part of the lunation.

This principle once admitted, it is easy to understand the method used by M. Gallé-Defond, who varies the times of sowing according to the results to be obtained.

But does the sap between the time of New Moon and Full Moon rise more abundantly than during the following days? This is the whole problem.

There seems no doubt that the question can be solved when reduced to this form, but the experiments must be carried out with method and precision. Certain plants seem to be specially adapted for the test.

"In the cultivation of mushroom beds," says M. Cordier, a gardener of Lunéville, "I have always remarked that there was as abundant a crop between the 8th and the 15th day of the lunation as during all the rest of the month put together, and as the development of the mushroom takes 4 to 6 days, the rise of the sap would thus correspond to the first days of the Moon.

"A second observation refers to the cultivation of the melon. I believe I have very often remarked that the fruit formed much better during the Old Moon than during the New; and as to obtain well-formed fruit, one must avoid producing an excessive supply of sap, whether by watering or by heat—it would seem that the New Moon produces this excess of sap, which in normal times one can avoid."

With regard to the cultivation of the beetroot, M. Compiègne and his sons, at Cremarest (Pas-de-Calais), have remarked a point that confirms the preceding observations. If one cuts a beet across, one can count concentric circular rings around its core ; now the number of these rings is equal to that of the revolutions of the Moon since the springing up of the plant.

These extremely interesting points may be compared with others that are less known.

M. Gallé-Defond tells us that one of his friends, a planter in America, has declared to him that some kinds of trees have marked on their cross sections not only the rings indicating the years of growth, but also what really are concentric lunar circles.

The same remark is made by M. Jacques, a landed proprietor in New Caledonia, where for several years he has been exploiting great tracts of forest.

" In France," he tells us, " trees are only cut in winter, for the excellent reason that if the thinning is done in the winter, when the circulation of the sap is least active, the trees continue to grow better, while those that are thinned out in summer, in June or July, for instance, either grow badly or not at all. Further, it has undoubtedly been shown that wood cut in summer does not keep well, and soon after it is felled is attacked by mushroom growths and insects, which cause it to rot quickly

Photograph by G. E. Hale.

THE MOON'S SURFACE.

and make it useless for any purpose. This can be very well explained by a kind of fermentation taking place in the tree if it is cut down at the moment when it contains an abundance of sap.

"Here the Moon is not to blame, for it is the Sun that favours this great production of sap, that afterwards leads to decay.

"But in New Caledonia, where the temperature is from 73° to 77° in winter and from 77° to 86° in summer, the rapid decomposition of wood cut during the New Moon cannot be attributed to the same causes, unless it is admitted that in tropical countries the sap circulates in greater abundance during the New than during the Old Moon.

"I must tell you that at the outset I had no belief whatever in any influence of the Moon on the preservation of wood. It was all very well for the natives to say to me, 'Him not good to cut at present, him wait to cut till good.' I paid no attention, and I had a costly experience of it.

"For all the woods, even those of the hardest structure, that were cut during the New Moon, were very soon worm-eaten, while those felled during the Old Moon remained, even after the lapse of many years, in an excellent state of preservation. And this was not in any one month rather than another, for I had the curiosity to repeat the experiment during every lunar month of the year, and the result was always the same.

"The *Bancoulier* tree, for instance, which is very soft wooded, if felled and cut up in the New Moon literally went to dust in six months; the same wood felled and cut up during the Old Moon kept without change for years.

"It does not follow from this that the Moon exerts a direct action on timber cut during this or that phase, but I simply note the fact that wood cut during a certain period of the lunar month rapidly deteriorates, while that cut in another period of the Moon keeps in the normal way."

We might quote here M. Gallé-Defond's experiments on the cultivation of fruit trees. We shall content ourselves merely with noting that, according to him, it is most important not to plant any fruit tree or shrub during the first fortnight of the Moon if one wants to have a good supply of fruit from it.

To sum up, it would seem that the Moon exerts some influence upon vegetable life, and if in our lands the experiments are not all conclusive, it is because frequently the lunar action, perhaps a very slight one, is counteracted by changes of the weather which diminish its effect or neutralise it altogether.

And the best proof of it is afforded us by facts observed in tropical countries, where there is nothing to disturb the action of our satellite.

If these conclusions are justified, we ought to be able to note this lunar influence all the more clearly as we turn our attention to vegetable phenomena of a more rudimentary class.

And this is precisely what is shown by the experiments of M. Carbonnier on cryptogamic vegetation, principally that which grows in stagnant waters.

The maximum intensity of growth of this kind always corresponds to the time of the Full Moon.

These are undoubted facts; whatever be the explanation, they will remain none the less certain.

To whatever theory we may appeal, it is a fact known to all botanists that the growth of plants depends on the carbonic acid diffused in the atmosphere; now this phenomenon takes place above all under the action of light. No light, no production of chlorophyll, and therefore no vegetable growth.

One might thus explain why seeds sown at the New Moon develop more rapidly than if they had been placed in the ground at the Full Moon.

In the former case, when the seedlings push through the surface of the ground the Moon gives them some of the light they need to absorb carbon and grow ; in the second case they come out of the ground when the Moon is below the horizon, and are thus deprived of its luminous rays during the nights.

And then, who can tell us what is the inner mechanism of vegetable growth, presiding over the life of the microbe as well as that of more highly organised structures ? What is the action of the rays of the spectrum, of chemical radiations, and of unknown vibrations ?

Truly, instead of denying facts, we would do better to study them more closely. The explanation will come after that.

X

ASTRAL INFLUENCES AND ASTROLOGERS

The search for the causes of things is most certainly a deep-seated tendency, a law of the mind—a law that dominates it forcibly and inevitably—for through all time we see humanity seeking to find behind the effects it has observed a reason capable of giving a logical explanation of them.

If those causes eluded his search through his invincible ignorance, man very often sought for an explanation of the phenomena around him in the forces of Nature personified for the purpose, and endowed by his imagination with the most extravagant powers.

Thus, as the vault of the skies attracted the attention of primitive peoples, the constellations were soon supposed to play a preponderating part in human destinies and in all the actions of life.

Virgil tells us how Orion was associated with the coming of rain, and the Pleiades forecasted stormy weather.

But the presence of the Sun and Moon or the planets above the horizon, and later on the calculated positions of the heavenly bodies, became, in the hands of the astrologers, the basis of a complete science for the prediction of the future.

The Sun, as we know, in the course of the year pays a visit to each of the twelve constellations of the zodiac. An individual born in such or such a month was therefore supposed to be under the influence of this or that constellation. Thus fatalism had a fine field.

Don't smile at all this. Why, even to-day there are plenty of almanac-makers that would think they were not living up to their reputation if they did not give horoscopes taken from the position of the Sun in each sign of the zodiac.

Were you born under the sign of the Bull or the Ram? You are assured of material prosperity. The Scorpion predicts a contrary destiny for you; the Lion presages heroes; the Virgin forecasts a pure-minded disposition; Capricorn brings riches—and so forth.

Unfortunately the diversity of the life-destinies

From the Photographic Atlas of the Paris Observatory.

REGION BETWEEN THE "MARE IMBRIUM" AND THE NORTH POLE OF THE MOON.

At the top are the *Mare Imbrium* (Sea of Rains), Laplace Promontory and the *Sinus Iridum* (Gulf of Rainbows). Lower down, the large mountain ring with a dark interior is Plato. Below this is the *Mare Frigoris* (Sea of Cold) and then the North Pole of the Moon with the mountainous region around it.

(Reversed image.)

of men born under this or that sign has always been so great that the astrologers soon found the need of additional explanations.

It was then that they brought in the action of the Moon and the planets.

Mercury was the patron of the arts; Mars inspired to war; Venus could only keep to her mythological character; Jupiter indicated to mortals born under its influence that they were destined to the greatest triumphs; witness this passage from a book on Astrology of the days of Louis XIII: "Jupiter in the first sign of the zodiac makes nobles, men of power, bishops, rulers, sages, philosophers, merchants, bankers."

Saturn was associated with the greatest sorrows; it was considered an unlucky star. What would they have said of Uranus and Neptune? But they were unknown at that time.

All this seemed quite natural, and no one was tempted to laugh at it; nevertheless, one thinks one must be dreaming as one reads some of the manuscripts of the Middle Ages and the extraordinary horoscopes they contain.

The doctrines of the astrologers were held in high honour among the Arabs, and from them passed into Spain; but it was especially on the return of the Crusaders from the East that they spread over Western Europe.

Then kings and princes had their official astrologers, and these poor people had too often reason to repeat the words of Scripture—"*Nolite confidere in principibus*" ("Put not your trust in princes").

Flattery, generally so successful with the great, was often no help to the astrologers, and they had to rack their brains to find something better.

Thus one day, when he was in a bad humour, Louis XI sent for his astrologer Galeotti, and put a very embarrassing question to him.

"As by your own claim you know everything," said the king to him, "tell me when you will die."

Alas for Galeotti! He knew the king had told his people that as soon as they had a sign from him they were to put the astrologer into a sack and throw him into the river.

But his ready wit saved him from this awkward situation.

"Sire," he replied at once, "I have carefully consulted the stars on this subject, and they tell me I shall die just three days before your Majesty."

The king was very superstitious, but perhaps he did not believe this ; nevertheless, he took care not to carry out his plan. "After all," he thought, "one can never be certain."

Strange to say, and to a certain point this is an excuse for the almost universal belief in Astrology at a time when modern Astronomy had not yet revealed the mechanism of the heavens, the astronomers themselves gave the example, and most of them united the professions of astrologer and astronomer.

It is true that many of them regarded Astrology as only a necessary expedient for earning their daily bread and an indirect means of enabling them to devote themselves to more serious work.

In his *Ephemerides* for 1469 Johann Müller, who is better known under the name of "Regiomontanus," investigates the question of the aspects of the Moon under which it is best to perform the operation of blood-letting, and on what parts of the human body the various signs of the zodiac have a special influence.

We find, indeed, such indications in an old drawing in a manuscript in the library of Bourges.

Taurus the Bull influences the neck and the upper part of the throat; Cancer, the chest, lungs, stomach, etc.

Stoefler, an able mathematician, who was a professor at Tübingen, believed in the influence of the heavenly bodies on events here on Earth.

Having calculated that there would be a conjunction of the planets Mars, Jupiter, and Saturn in the month of February 1524, he predicted a universal deluge at that date.

Could it be otherwise, seeing that this heavenly phenomenon would take place in the sign of the Fishes?

The prophecy made a great stir, and a doctor of Toulouse, named Auriol, took it so seriously that he immediately had a great vessel constructed on the plan of Noah's ark.

February came—and it was the driest month of the year.

It is said that Jerome Cardan drew a horoscope for Edward VI.

But he piled up such a series of unsuccessful prophecies that at last, disgusted with his failures, he ended by predicting his own death for the year 1570.

As if he meant to show that, once in a way, his prophecies could be correct, he starved himself to death.

Tycho Brahé (1546–1601) did not, as a rule, make any distinction between Astrology and Astronomy; these two sciences were only one at that time, or rather the true Astronomy had not yet come into existence.

Though he had something like a real vocation for the study of the stars, Tycho had all the trouble in the world to accomplish his plans.

His father, Otho Brahé, Lord of Knudstrup, in Scania, had been brought up in the complete ignorance that then befitted a nobleman. However, he consented to let his son go first to Copenhagen, and then to Leipsic, to study law, but Tycho eluded his tutor's vigilance and spent all his nights in the study of the skies.

Though of a kindly and generous character, and endowed with the noblest feelings, he had a hasty and violent temper. This was the source of endless trouble for him that followed him through all his life.

It appears that while he was a student at Leipsic he drew his own horoscope, and was startled to find that the scheme, where the influence of the planet Mars came into it, presaged for him a disfigurement in the face.

There was nothing to justify this indication, till one fine day he picked a quarrel with one of his fellow-students over a theorem in geometry.

A duel was arranged. On a dark night by the light of a smoky torch the two opponents attacked each other furiously, and after they had crossed weapons several times, a sword-cut took off Tycho Brahé's nose.

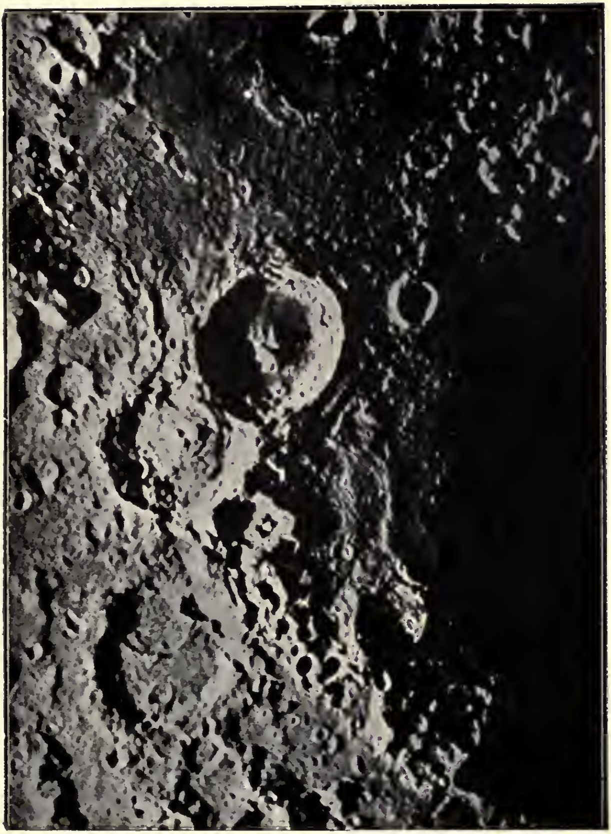
The horoscope was fulfilled.

Tycho was not too downcast at his unfortunate adventure; his wound healed, and he made himself an artificial nose of gold, silver, and wax. Contemporaries tell us that the imitation was so perfect that no one ever noticed his loss.

Even Kepler, who was to make himself famous by the discovery of his immortal laws, was obliged to play the astrologer.

At every turn his works refer to the wonderful properties of numbers, to disturbing influences, the conjunction of planets, etc., etc.

He was only twenty-four years old when, in 1594, he was appointed professor at Grätz, in Styria. Besides his work as a teacher he was en-



The Three Chief Mountain Rings are (from Top to Bottom) Theophilus, Cyrillus, and Catherine.
(Erect image.)

trusted with the making of almanacs—predictions as to the weather, horoscopes, all that kind of thing was then very closely connected with the astronomical figures relating to the positions of the stars.

Later on he had to continue the practice of this wretched profession in order to support his large family, and he often drew the horoscopes of princes, who summoned him to their courts "to know their fate by the stars."

Kepler, in reality, had no belief in these practices, and we have the proof of this very clearly in a passage in his writings: "What have you to complain of, you over-scrupulous philosophers, if a daughter (Astrology), whom you think foolish, supports a wise, though poor, mother (Astronomy); if this mother is tolerated among men more foolish still, only for the sake of these same follies? If men had not had the credulous hope of reading the future in the heavens, would you ever have been wise enough to study Astronomy for its own sake?"

And in fact, in Kepler's days, alchemists, astrologers, and magicians swarmed to such a degree that L'Estoile wrote in his *Journal de Henri III*:

"In the time of Charles IX these vermin had secured such immunity in Paris, that there were as many as 30,000 of them, as the chief of them admitted in 1572."

Henri II of France often consulted the famous Nostradamus, who wrote his *Centuries*, a collection of prophecies in which no one ever understood anything—very likely not even their author.

This work, of which Henri II accepted the dedication, was, however, of this much service to Nostradamus, that it led to his being summoned by the King, who gave him 100 crowns in gold and sent him to Blois to draw the horoscopes of his sons, the young princes.

New honours were lavished on Nostradamus as the result of this mission, and later Charles IX and Catharine de' Medici attached him to their service.

The latter soon began to set the very highest value on Astrology. She spent absurd amounts of money on building observatories merely for the purpose of being herself able to consult the stars.

One of the most famous of these was that of the Hôtel de Soissons. It consisted of a column nearly 100 feet high, which the pickaxe of the town improver has spared to our day.

This Hôtel de Soissons has a whole curious story of its own connected with Astrology.

We shall let Dulaure himself tell it to us:

"Why did this queen—after having built the palace of the Tuileries, expended considerable sums upon it, and adorned it with the work of the most famous artists and all that luxury could desire in the way of comfort and elegance—leave the place for good and all soon after the building was completed? Why did she take a dislike to the palace, and, at a time when the finances were exhausted, buy the Abbey of Saint-Maur des Fosses to erect a residence there for herself? Why did she then abandon this project, only to take up another, and buy the convent of the Filles Pénitentes? Why did she disturb the nuns who lived there by transferring them to the Abbey of Saint-Maur, and secularise the monks of the latter abbey in order to transfer them to the Hospital of Saint-Jacques du Haut Pas? Why was she obliged to ask of her son, the king, the permission to carry out these changes, and of the Pope bulls to ratify these transfers and secularisations, and of the Parlement de Paris the registration of all these acts? Why, finally, did she order all these changes, and especially give up the Tuileries, to build and go to live in a new residence? Here is the reason—Catharine de' Medici was frightened at the prediction of an astrologer, who foretold that she would die in a place called Saint-Germain. Now the Tuileries were situated in the parish of Saint-Germain l'Auxerrois. 'It was at once noticed,' says Mézeray, 'that she superstitiously avoided all the places and churches that bore that name. She would not again go to Saint-Germain-en-Laye, and because her palace of the Tuileries was in the parish of Saint-Germain in l'Auxerrois, she even had another built, namely, the Hôtel de Soissons near Saint-Eustache.'

"There is something satisfying to self-love when one sees ridiculous actions on the part of powerful people who have aspired to celebrity. This queen, so powerful, so feared, so imperious, debased herself by her stupid credulity to the level of the very lowest class of society. She believed what to-day the old women of the most out-of-the-way villages would blush to believe; she believed in the predictions of magicians, and she, who struck terror into the hearts of so many, was herself terrified at the oracles of the wretched astrologer.

"This hôtel, which in the fourteenth century had borne in succession the names of de Nesle, de Bohême, and de Behaigne, and in the fifteenth that of d'Orléans, then that of the 'Filles Pénitentes' when the nuns of that order occupied it, was called the Hôtel de la Reine in 1571, when it became the property of Catharine de' Medici. After the death of the queen it was called the Hôtel des Princesses, and finally the Hôtel de Soissons as at present.

"Catharine de' Medici had had erected there, after the plans of Bullant, and in the angle of a side court, a fluted Doric column of great height, to be used by herself as an observatory. It adjoined and was in communication with the Hôtel de la Reine. This column is the only structure belonging to the Hôtel de Soissons that survives. It is still to be seen close to the buildings of the Halles; it has a winding stair in its interior. The queen used to ascend it to consult the stars, and seek to find in their positions the promise of a happiness that those who reign amid crimes never find on this earth."

The favourite astrologers of Catharine de' Medici were Régnier, and a certain Cosmo Ruggieri, a native of Florence. It was the latter who made the prediction as to the place of the princess's death.

But notwithstanding all the precautions she took, this is what happened. At least it is what certain historians tell us.

After having fled from all the Saint-Germains in the world, one day, when Catharine was at Blois, she had a severe attack of fever on hearing the news of the assassination of the Duke of Guise. At once she sent in terror for a priest and asked his name.

"The Père Saint-Germain, preacher to the King," was the reply.

"Ah!" exclaimed Catharine, "I am a dead woman!"

And in fact she died next day, January 5, 1589.

In the following reigns there were perhaps fewer astrologers, but their influence did not diminish.

At the moment when his son was born Henri IV desired his doctor and the astrologer Larivière to draw the horoscope of the royal child.

The astrologer got very well out of the business by declaring that the young prince was born under the sign of the Balance, and this was why Louis XIII, from his very cradle, was surnamed "the Just."

So it was a very simple business!

An astrologer was also on duty at the birth of Louis XIV and drew his horoscope with equal success.

How could it have been otherwise, since even the astronomers lent themselves to these practices?

Many of them even believed in their forecasts—for instance, the famous Morinus, who did not hesitate to predict to people, on all manner of occasions, what would happen to them at an early date.

Thus it was that he announced to his colleague Gassendi as the time of his death the end of the coming July of 1650. "But," the famous Canon of Digne used to delight in telling his friends, "I was never better than at the fatal epoch marked out by the prediction of Morinus."

And a little later have we not the Comte de Boulainvilliers in concert with the Italian astrologer Colonna predicting the death of Voltaire at the age of thirty-two. "Everyone knows," remarks

Arago when relating the fact, "how that prediction was fulfilled!"

Gradually, however, the fashion seemed to change and we see the "most excellent mathematicians and extractors of quintessences," of whom Rabelais had made sport, turning their attention to almanacs or "prognostications."

Thus in this connection we read in the second edition of the *Astronomie de M. Lalande*, printed in 1771, this characteristic passage:

"It is not without difficulty that at last the philosophic spirit has dissipated these errors; at the beginning of this century people at times came to consult the astronomers of the *Académie* as to the future, and in 1705 M. Lieutaud thought it well to print as a preface to the *Connaissance de Temps*: 'No predictions will be found here, because the Academy has never recognised the solidity of the rules given by the Ancients for predicting the future by the relative positions of the stars.'

"If one reads a letter in the *Mercure de France* of 1763, in which I told of the anxiety of the Sultan of Turkey to obtain all the works published by the astronomers of the Academy, it will be remarked that he asked especially for any predictions made as to the future by the science of the stars. Perhaps his Highness only wanted our books of astronomy in the hope of finding in them the fate of the Powers, who seemed intent on mutual destruction."

Nowadays no one any longer ventures to consult men of science as to reading the future in the stars, but the bent of the popular mind has not altered.

Did not Napoleon go to have "his good fortune" told by the celebrated card-reader Mademoiselle Lenormand ?

It is not long since I had proposals from more than one contemporary astrologer to draw my horoscope.

The card-readers and the necromancers of spirit-séances find each year Paris newspapers ready to publish their ambiguous and grotesque predictions.

The fortunes they make for themselves in this "noble profession" are one more proof of the ignorance and insurmountable credulity of the public.

But let us stop, for one might write volumes on such a subject, and probably without advantage to anyone.

Let us leave the astrologers to draw their horoscopes. The planets are too far off to exert an influence on the life of any one of us. Even the perturbations they cause in the earth's movements are infinitesimal.

But we cannot say as much of the Moon, and I confess that here those who take an interest in the influence of the heavenly bodies have a better case.

What effect can the Moon have on the development of the animal organism, and what influences come from it? This is what it remains for us to examine.

XI

THE ACTION OF THE MOON ON MEN AND ANIMALS

If it may be admitted that the Moon exerts some action on the phenomena of vegetation, one cannot see *a priori* any reason why animal growth should not be, up to a certain point, dependent on the same influence.

Everyone knows the effects of spring on the animal organism, and, as far as I know, no one has found a complete explanation for it.

At the moment when the sap begins to rise freely in the plants, it seems as if at the same time a "revival" comes over men and animals.

If, then, the Moon promotes by its action the rise of the sap, or the chemical combinations of the vegetable cell, one can imagine the possibility of a similar action on the animal cell, which in its inner structure differs very little from the former.

And in fact there is no lack of observations bearing on this point. One would want whole volumes to classify them all.

M. Latourte of Dieppe wrote recently :

"I keep some hens, and during forty years I have reared a good number.

"Now, each time that I put eggs to be hatched, the chickens hatched out during the period from the First Quarter to the Full Moon break through the shell more easily, and are more vigorous than their fellows who come out in the period from the Last Quarter to the New Moon."

This confirms the observations of M. Gallé-Defond, who is a poultry farmer as well as a horticulturist :

"The Moon," he writes, "is not without some influence on the success or failure of the hatching out of chickens or goslings."

The growth of animals born at the beginning of the lunation follows the same rule as that of plants. It appears to be more rapid than that of animals born in the waning of the Moon.

So perhaps our ancestors were not so foolish when they preached their plan of having their hair cut and their beards trimmed at the New Moon.

Even the wine industry has the benefit of these prescriptions. So we are told that the racking of the wine should never be done towards the end of the lunar month.

It is now known that the fermentation of wine depends on the development of a micro-organism—of a cell—and if we admit the influence of the Moon on organic beings, it will be easily understood that here too its influence would come under a general law.

So we can only repeat what we have said in previous chapters: Light is only a form of energy, and we are very far from having analysed all its radiations.

Perhaps it is in this mysterious influence which promotes the development of the cell, and is favourable to the general activity of the human body, that we must look for the explanation and origin of the word *lunatic*, applied to persons subject intermittently to loss of reason and attacks of madness.

With the ancients there was no doubt as to the action of the Moon on the mental state of certain subjects.

In a book of 1399, a learned history of the madness of Charles VI of France, we read:

"The King, who had recovered his health, kept the feast of Easter in his royal residence of Saint-Paul. . . . Every one was rejoicing at his recovery, but this happy state of things did not last long. That same year he relapsed six times into madness, either at the New or at the Full Moon."

If this were an isolated fact, evidently it would prove nothing, but we shall see that it is corroborated by other testimony of the same kind.

In a work on medicine published in 1578 by Dr. Joubert of Montpellier, the falling sickness, or epilepsy, as well as melancholy, are classed among the illnesses that quite evidently depend upon the course and phases of the Moon. Menuret considers skin diseases to be those the recurrences of which are most indisputably connected with the lunar phases. He asserts that he himself had observed in 1760 a cutaneous attack of a patient increasing continually during the waning of the Moon, and reaching its maximum of intensity towards the time of New Moon, when it covered all the face and chest and caused unbearable irritation. After this epoch all the symptoms gradually disappeared, and the face became clear, but the same symptoms were seen to begin again as soon as the Full Moon had passed.

In another disease of this class the same doctor noticed that a similar series of phenomena appeared in a reversed order.

Whatever be the opinion one may profess on the mechanism of the development of such maladies, it would not be absurd to compare them to those nervous phenomena that to a certain degree are dependent on lunar influences. Mead has cited the case of a child that always suffered from convulsions at the time of the Full Moon, and Piso observed that an attack of paralysis recurred with every New Moon, that is to say, at the periods of least activity.

According to Menuret, with some epileptics the attacks recur at the moment of the Full Moon.

One does not at first sight see very well how our satellite can act in such a way, but we may at least point out that all nervous maladies, and in certain cases those that affect the terminations of the nerves in certain skin diseases, appear to be directly dependent on electrical influences. Now, there can be no doubt that, especially in the higher regions of the atmosphere, the charge of atmospheric electricity can vary under the influence of the Moon's light, and one might, strictly speaking, connect the two kinds of phenomena.

What further appears to corroborate these somewhat daring views is the mass of organic facts observed long since in hospitals in the cases of patients suffering clearly and exclusively from nervous troubles—vertigo, hysteria, somnambulism, etc.—in a way more or less in relation with the phases of the Moon.

This was the opinion of the celebrated Gall, who declared that he had recorded, in the case of weakly persons, two epochs of irritability corresponding to the New Moon and the Full Moon.

The celebrated physician and astronomer Olbers attempted to make an experimental verification of these facts, and after having been long in medical practice, he denied them all absolutely.

Those who are of the opposite opinion object to this way of looking at the matter that the instances observed in our countries are much less numerous than those of tropical lands.

But however this may be, Balfour felt satisfied that in Bengal the progress of certain maladies, and particularly that of intermittent fevers, follows the course of the Moon.

Bruce asserts that more than once he observed that the Moon exercises such an influence on epileptics, and with such regularity that it is always on the third day of the Full Moon that the paroxysm of the illness ended in an intermittent fever.

It was, besides, a generally received opinion among Orientals that epileptics were agitated by the Moon, and it was on account of this opinion that they were given the name of lunatics, a term afterwards applied to the insane.

The observations of Fontana bearing on the same subject were also made in hot countries, but the case that most clearly points to lunar influence is that reported in the first volume of the *Memoirs of the Royal Academy of Madrid.* The patient in question was attacked periodically with a difficulty of breathing, which became more marked at the approach of New and Full Moon.

This singular illness lasted for several years in succession.

It is probably to the fewness of such observations in the hospitals of France and Europe that one must attribute the opinion of pathologists, who are little disposed to accept the theory of lunar influences on their patients.

Nevertheless it is the opinion of several alienists of our own day that their patients are more agitated at the period of the Full Moon than at that of New Moon.

It might be well to take up the question again both here at home and in our tropical possessions.

It would be a fine subject for a thesis for the doctor's degree for such of my pupils as are short of suggestions or of material.

Experience alone can decide the question. What we must, however, insist upon is that our organism is infinitely more sensitive to outside influences than much of the apparatus invented by modern physicists, and that, besides, the human body must be a receiver for wonderfully synchronised waves of radiations still unknown to us; that we have an electric or magnetic sense, which permits us to perceive variations of this kind, though of infinitesimal amount; and that the learned men of our day, when they talk of "nervous influx," are hiding under this term their profound ignorance of the mechanism that regulates all our organic actions.

We conclude that we should continually study matters, and not rashly cast aside the opinions of our ancestors, especially when we find them supported by facts of which the authenticity cannot be called in question.

The Moon, that great satellite, so near our earth, which from the mechanical point of view causes such enormous perturbations to our world, should not be treated as a negligible factor from whatever point of view we consider it.

There seems no doubt about its having some influence on life, but to what degree is this exerted? That is the new question that appeals to learned and ignorant, physicist and physician, physiologist and astronomer.

These serious considerations are, it seems to me, calculated to restore to their due place certain branches of lunar research, which have been too much neglected by students of the heavens. Perhaps they will, moreover, avail to merit for me the forgiveness of the astrologers, of whom I have said so many hard things in the course of this work.

* * * * *

It is not generally known that the study of the Moon is within the reach of low-powered instruments.

One need only have a comparatively small telescope to make very interesting observations.

We have seen that many selenographers had at their disposal only instruments of small aperture and short focal distance. They have, all the same, done useful work in exploring the surface of our satellite.

Why should not a good many of my readers do the same.

And here one must take care not to fall into a very widespread error. When one sets about the study of Physical Astronomy one imagines that one will see much better by using high magnifying powers. It is a great mistake.

With telescopes of low power, objects are always seen very sharply defined, and it is thus one should begin to observe.

First of all, train your eyes; the faculty of penetrating vision will come later.

It is rather a long task, but the trouble is well repaid.

Throughout you will be able to see enough of detail to take a great interest in it, and so much that you will be embarrassed when you have to reproduce what you see in a sketch.

Since the application of photography to the study of the Moon, there has been too much neglect of direct vision and the study of detail; this should be taken up again, unless we are merely to mark time and make no progress.

Lunar photographs are useful in the sense that they fix the topography of our satellite in a definite way, better than this can be done by micrometer measurements. But when it comes to observing fissures, small craters, passing shadows, and elevations of no great height, nothing is equal to direct observation with the eye.

A telescope of 108 millimetres shows far more objects than the best photographs.

Finally, there are regions which should be specially studied. They are those that present certain curious peculiarities from the geological and volcanic point of view; others may be recommended by their picturesque character, as, for instance, the "Straight Range" of the Moon, of which we have already spoken, or the famous woman's head in the Moon so well known to the old selenographers.

In his first maps Cassini had, in fact, drawn at the western end of the "Sinus Iridum" the promontory of the Heraclides in the form of the head of a young woman. It was long believed that the famous astronomer merely intended by this means to distinguish his map from those that preceded it, and thus to sign it, so to say.

And it was not till long after that this strange appearance was again seen. In the drawing of Schroeter the form shown by Cassini is not to be recognised. That of M. Mabire gives it, however, but with the appearance of an aged woman.

One evening, when I was studying the Moon, I saw the same promontory once more under a form very like that in Cassini's drawings. The apparition with its extended wings looked rather like a nymph or a naïad.

There is really here, then, a mere question of lighting. When closely surveying the surface of the Moon, it sometimes happens that one grasps details that only present themselves on rare occasions, as the result of libration varying to an endless extent the angle at which the solar rays fall.

One can also with the help of a telescope of low power secure interesting photographs of our satellite.

As is well known, all that is necessary is to replace the ordinary eye-piece by that of the instrument, or, better still, fit the camera to the telescope, leaving the eye-piece in position.

In an instrument of small aperture the difference between the optical and chemical focus is almost inappreciable, and one soon succeeds in finding the right position after a few trials.

This method is of the greatest service when it is a matter of photographing the phases of an eclipse of the Moon or the Sun, and I have often used it successfully on these occasions. An exposure of a fraction of a second gives excellent results.

With these practical hints I close the volume. I shall be happy if I have succeeded in developing in some of my readers a taste for those lunar studies that are within the reach of anyone who is in earnest about them.

LIST OF 348 OBJECTS SHOWN ON THE MAP OF THE MOON, DRAWN BY THE ABBÉ MOREUX

(CRATERS, MOUNTAINS, AND INEQUALITIES OF THE SURFACE)

The letters N.E., S.E., N.W., S.W., signify North-east, South-east, North-west, South-west, and indicate in which quarter of the Moon the objects are to be sought for.

Abenezra	S.W.	Apian	S.W.
Abulfeda	S.W.	Apollo	N.W.
Ænarium (promontory)	S.E.	Arago	N.W.
Agatharchides	S.E.	Aratus	N.W.
Agrippa	N.W.	Archimedes	N.E.
Airy	S.W.	Archytas	N.W.
Albategnius	S.W.	Argelander	S.W.
Alexander	S.W.	Aristarchus	N.E.
Alhazen	N.W.	Aristillus	N.W.
Almanon	S.W.	Aristotle	N.W.
Alpetrages	S.E.	Arzachel	S.E.
Alps (Mts.)	South	Atlas	N.W.
Alps (Valley of)	S.W.	Autolycus	N.W.
Altaï (Mts.)	S.W.	Azophi	S.W.
Anaximander	N.E.	Azout	N.W.
Anaximenes	N.E.		
Ansgar	S.W.	Bacon	S.W.
Apennines (Mts.)	N.E.	Bailly	S.E.

Baily	S.W.
Ball	S.E.
Barocius	S.W.
Bayer	S.E.
Beaumont	S.W.
Behaim	S.W.
Berosus	N.W.
Bessarion	N.E.
Bessel	N.W.
Bianchini	N.E.
Biela	S.W.
Birt	S.E.
Boguslawski	S.W.
Bohnenberger	S.W.
Bond	S.W.
Bonpland	S.E.
Borda	S.W.
Boscovitch	N.W.
Bouguer	N.E.
Boulliaud	S.E.
Boussingault	S.W.
Bouvard	S.E.
Bradley (Mts.)	N.W.
Briggs	N.E.
Buch	S.W.
Burckhardt	N.W.
Burg	N.W.
Busching	S.W.
Calippus	N.W.
Campanus	S.E.
Canon	N.W.
Capella	S.W.
Capuanus	S.E.
Cardan	N.E.
Carlini	N.E.
Carpathians (Mts.)	N.E.
Cassini	N.W.
Catherine	S.W.
Caucasus (Mts.)	N.W.
Cavendish	S.E.
Cepheus	N.W.
Chacornac	N.W.
Chevallier	N.W.
Cichus	S.E.
Clairaut	S.W.
Clavius	S.W.
Cleomedes	N.W.
Colombo	S.W.
Condamine	N.E.
Condorcet	N.W.
Cook	S.W.
Copernicus	N.E.
Cruger	S.E.
Curtius	S.W.
Cuvier	S.W.
Cyrillus	S.W.
Cysatus	S.W.
D'Alembert (Mts.)	S.E.
Damoiseau	S.E.
Davy	S.E.
Dawes	N.W.
Delambre	S.W.
De la Rue	N.W.
Delisle	N.E.
Democritus	N.W.
Descartes	S.W.

Diophantes	N.E.
Dœrfel (Mts.)	S.E.
Donati	S.W.
Doppelmayer	S.E.
Drebbel	S.E.
Egedé	N.W.
Eichstadt	S.E.
Eimmart	N.W.
Encke	N.E.
Endymion	N.W.
Eratosthenes	N.E.
Euclid	S.E.
Eudoxus	N.W.
Fabricius	S.W.
Fermat	S.W.
Fernel	S.W.
Firmicus	N.W.
Flamsteed	S.E.
Fontana	S.E.
Fontenelle	N.E.
Fourier	S.E.
Fournier	S.W.
Fracastorius	S.W.
Fra Mauro	S.E.
Franklin	N.W.
Fraunhofer	S.W.
Frisius (Gemma)	S.W.
Galileo	N.E.
Gambart	N.E.
Gartner	N.W.
Gauricus	S.E.

Gauss	N.W.
Gay-Lussac	N.E.
Geminus	N.W.
Gérard	N.E.
Goclenius	S.W.
Godin	N.W.
Grimaldi	S.E.
Gruemberger	S.E.
Gruithuisen	N.E.
Guerikê	N.E.
Guttenberg	S.W.
Hadley (Mts.)	S.W.
Hæmus (Mts.)	N.W.
Hagecius	S.W.
Hainzell	S.E.
Halley	S.W.
Halm	N.W.
Hansen	N.W.
Hansteen	S.E.
Harbinger	N.E.
Harding	N.E.
Harpalus	N.E.
Hecatæus	S.W.
Heinsius	S.E.
Helicon	N.E.
Hell	S.E.
Hercules	N.E.
Hercynian (Mts.)	S.E.
Herigonius	S.E.
Herodotus	N.E.
Herschel	N.E.
Herschel, C.	N.E.
Herschel, J.	N.E.

Schickard	S.E.
Schiller	S.E.
Schrieter	N.E.
Schubert	N.W.
Secchi	N.W.
Segner	S.E.
Seleucus	N.E.
Sharp	N.E.
Short	S.E.
Snellius	S.W.
Sommering	N.W.
Sosigenes	N.W.
South	N.E.
Stadius	N.E.
Steinheil	S.W.
Stévin	S.W.
Stiborius	S.W.
Stoefler	S.W.
Strabo	N.W.
Straight Range	N.E.
Street	S.E.
Struve	N.E.
Taruntius	N.W.
Taurus (Mts.)	N.W.
Taylor	S.W.
Thales	N.W.
Theatætus	N.W.
Thebit	S.E.
Theophilus	S.W.
Timæus	N.E.
Timocharis	N.E.
Tobias Mayer	N.E.
Torricelli	S.W.
Trallus	N.W.
Triesnecker	N.W.
Tycho	S.E.
Ukert	N.W.
Ulugh Bey	N.E.
Vega	S.W.
Vendelinus	S.W.
Vieta	S.E.
Vitello	S.E.
Vitruvius	N.W.
Vlacq	S.W.
Walter	S.E.
Webb	S.W.
Weigel	S.E.
Werner	S.W.
Wichmann	S.E.
Wilhelm I.	S.E.
Wolf (Mts.)	N.E.
Wurzelbauer	S.E.
Zagut	S.W.
Zuchius	S.E.
Zupus	S.E.

OBJECTS TO BE STUDIED ON EACH DAY OF THE LUNATION

2nd Day.—Mare Crisium.—Messala.—Sunrise on the Sea of Humboldt.—Langrenus, Vendelinus, Condorcet, Hansen, Gauss, Hahn, Berosus.

3rd Day.—Craters in the Mare Crisium.—Taruntius, Picard, Fraunhofer, Vega, Pontécoulant, Cleomedes, Fournier, Petavius, Endymion, Messier, Vlacq.

4th Day.—Mare Nectaris.—Macrobius, Proclus.—Sunrise on Fracastorius, Rheita, and Mætius, with the valley that separates them.—Guttenberg, Colombo, Santbech, the mountain region to the west of the Mare Serenetatis, Hercules, Atlas.

5th Day.—"Marsh of Sleep," Plana, Capella, Isidore, Polybius, Piccolomini, Vitruvius, Littrow, Fabricius, Posidonius, Lemonnier, Theophilus, Cyril, Catherine.

6th Day.—Tacitus, Maurolycus, Barocius, Dionysius, Sosigenes, Abulfeda, Descartes, Almanon, Gemma Frisius, Pliny, Ross, Arago, Delambre, Aristotle, Eudoxus, Julius Cæsar, Linnæus, Ménélas.

7th Day.—Ptolemy, Albategnius, Manilius, Hyginus and its rills, Hipparchus, Autolycus, Aritillus, Cassini, Valley of the Alps, W. C. Bond, Walter, Miller, Lacaille, Apennines, Triesnecker and its rays.

8th Day.—Mare Frigoris, Arzachel, Alphonso, Alpetagrius, Bode, Pallas, Archimedes, Plato, Maginus, Moesting, Thebit, Murus Rectus, Saussure, Morel, Lalande, Kirch.

9*th Day.*—Tycho, Clavius, Eratosthenes, Stadius, Timocharis, Pitatus, Gruemberger, Mountains of Teneriffe, region to the west of Fontenelle, Gambart.

10*th Day.*—Sinus Iridium, Copernicus, Hesiod and the fissure to the east of it, Wilhelm I, Longomontanus, Heinsius, Pytheas, Lambert, Helicon, Wurzelbauer.

11*th Day.*—Boulliaud, Campanus, Mercator, Reinhold, Riphæan Mountains, Hippalus, Capuanus, Blancanus, Tobias Mayer.

12*th Day.*—Mare Imbrium, Gassendi, Aristarchus, Herodotus, Marius, Flamsteed, Schiller, Mersenne, Doppelmayer.

13*th Day.*—Schickard, Wargentin, Grimaldi, Hevelius, Seleucus, Cruger, Briggs.

14*th Day.*—Smith's Sea, Bouvard, Riccioli, Hercynian Mountains, Cardan, Cordilleras, Pythagoras.

LUNAR ELEMENTS

	According to Elger.	According to the Author.
Mean apparent diameter .	31′ 8″	31′ 3·26″
Maximum apparent diameter .	33′ 33·20″	—
Minimum apparent diameter .	29′ 23·65″	—
Real diameter in miles . .	2,160	
Volume (that of the Earth being 1).	$\frac{1}{49 \cdot 2}$ or 0·02033	0·0204
Mass (that of the Earth being 1)	0·0128 or $\frac{1}{81 \cdot 4}$	$\frac{1}{81 \cdot 5}$
Density compared to the Earth	0·60419	0·61
Density compared to water .	3·444	3·42
Extent of surface . . .	14,657,402 sq. miles	
Surface of the Earth . .	197,000,000 sq. miles	
Surface of the Earth being 1, that of the Moon.	$\frac{2}{27}$ or about 0·07407	
Force of gravity at the surface	$\frac{1}{6 \cdot 065}$ of that on the Earth	$\frac{1}{6}$
Proportion of surface of the Moon that is never visible.	0·4100	—
Surface of the Moon seen at at one time or another.	0·5900	—

<table>
<tr><th></th><th>According to Elger.</th><th>According to the Author.</th></tr>
<tr><td>Synodic month, or interval from one New Moon to the following New Moon (lunation).</td><td colspan="2">29 days 12 hr. 44 min. 2·684 sec., or 29·5305887 days</td></tr>
<tr><td>Sidereal month, or interval of time between two successive passages in front of the same star.</td><td colspan="2">27 days 7 hr. 43 min. 11·545 sec., or 27·3216614 days</td></tr>
<tr><td>Tropical month, or interval between two successive passages of the point Gamma (γ).</td><td colspan="2">27 days 7 hr. 43 min. 4·68 sec., or 27·321582 days</td></tr>
<tr><td>Anomalistic month, or interval between two passages through perigree.</td><td colspan="2">27 days 13 hr. 18 min. 37·44 sec., or 27·55460 days</td></tr>
<tr><td>Nodical month, or interval between two passages of the ascending node.</td><td colspan="2">27 days 5 hr. 5 min. 35·81 sec., or 27·21222 days</td></tr>
<tr><td>Mean distance in terms of the Earth's radius at the Equator.</td><td>60·27</td><td>—</td></tr>
<tr><td>Mean distance in miles . .</td><td>238,840</td><td>—</td></tr>
<tr><td>Maximum distance . .</td><td>252,972</td><td>—</td></tr>
<tr><td>Minimum distance . .</td><td>221,641</td><td>—</td></tr>
<tr><td>Mean excentricity of orbit .</td><td colspan="2">0·05490807</td></tr>
<tr><td>Mean inclination of the orbit of the Moon to the Ecliptic.</td><td colspan="2">5° 8′ 39·96″</td></tr>
<tr><td>Inclination of the axis of the Moon to the Ecliptic.</td><td colspan="2">87° 27′ 51″</td></tr>
<tr><td>Inclination of the Moon's equator to the Ecliptic.</td><td colspan="2">1° 32′ 9″</td></tr>
<tr><td>Maximum libration in latitude</td><td colspan="2">60° 44′</td></tr>
</table>

	According to Elger.	According to the Author.
Maximum libration in longitude.	70° 45′	
Maximum total libration at the centre of the Earth.	10° 16′	
Maximum diurnal libration .	1° 1′ 28·8″	
Angle subtended by a degree of lunar latitude and longitude in the centre of the Moon's disc at mean distance.	16·566″	
Length of a degree in these conditions.	18·97715 miles	
Lunar arc at the centre of the Moon's surface subtending an angle of a second of arc.	3′ 37·31″	
Period of like phase . .	59 days 1 hr. 28 min. = 2 lunations	
Or more exactly . . .	442 days 23 hr. = 15 lunations	

LIST OF THE PRINCIPAL LUNAR "SEAS"

On our English maps and diagrams of the Moon the old Latin forms of the names of lunar "seas" are generally used. In the following list some of the chief of these are given, with the corresponding English meaning :—

Mare Tranquillitatis	Sea of Tranquillity
Mare Fœcunditatis	Sea of Fecundity
Mare Serenitatis	Sea of Serenity
Mare Crisium	Sea of Crises
Mare Frigoris	Sea of Cold
Mare Vaporum	Sea of Vapours
Mare Imbrium	Sea of Rains
Mare Nubium	Sea of Clouds
Mare Humorum	Sea of Humours
Mare Nectaris	Sea of Nectar
Mare Australis	Southern Sea
Oceanus Procellarum	Ocean of Tempests
Lacus Mortis	Lake of Death
Lacus Somniorum	Lake of Dreams
Sinus Iridum	Gulf of Rainbows
Sinus Roris	Gulf of Dew

CHIEF CHAINS OF LUNAR MOUNTAINS

Name.	Greatest height. Feet.	Length. Miles.
Alps	10,760	—
Caucasus	18,700	—
Apennines	19,600	400
Carpathians	6,500	180
Chain of the Sinus Iridium	13,280	312
Taurus Mountains	9,840	—
Teneriffe Mountains	7,870	—
Harbinger Mountains	6,890	—
Hercynian Mountains	8,200	—
Pyrenees	11,800	190
Altaï Mountains	12,790	276
Riphæan Mountains	2,950	100
Percy Mountains	—	—
Leibnitz Mountains	25,590	—
Doerfel Mountains	25,590	—
Rook Mountains	24,600	—
D'Alembert Mountains	19,680	—

INDEX

In the following Index the names of objects in the Moon (mountains, seas, etc.) are printed in *italics*.

PRINTED BY
HAZELL, WATSON AND VINEY, LD.,
LONDON AND AYLESBURY.