Art. IV.—THE QUESTION OF LIFE ON MARS.

1. *Mars and its Canals.* By Percival Lowell. (The Macmillan Company, New York and London, 1907.)
2. *Is Mars Habitable?* By Alfred Russel Wallace. (Macmillan & Co., London, 1907.)

TWELVE years ago we wrote of a book on Mars, then newly published: 'As a contribution to science, this pleasant 'and clever work can scarcely be taken quite seriously.' Its author, Mr. Percival Lowell, had just finished his first season's work at the new observatory which he had built at Flagstaff, in Arizona, 'where the forests and the quarries are under the clear 'remote skies.' * Full of enthusiasm for the idea of life in Mars which had been spread by the sensational newspaper boom that followed the favourable opposition of the planet in 1892, Mr. Lowell had seized upon the truth that a serene and steady air is above all things necessary for success; had scoured the world to find this air; had found it in Arizona, commanded the building of a big telescope there, and left Boston in hot haste with the announcement that 'there is strong reason to 'believe that we are on the eve of pretty definite discovery in 'the matter,' of life on other worlds. In less than two years he had published the brilliant and diverting piece of special pleading which we then noticed, and the judgement of the scientific world coincided with that which we had ventured to express, that the work could scarcely be taken quite seriously.

The work which has come from the Lowell Observatory in recent years has made it quite impossible to maintain this position. Mr. Lowell has been in deadly earnest. At every opposition the planet has been studied with a persistence that has no parallel since the days of Schiaparelli, and under conditions both of instrument and of climate that he could not command. Work has begun long before other astronomers have thought it worth while to turn their telescopes on the planet; it has been carried on for weeks after others had thought that the planet had moved too far away for anything to be made of it. Would-be destructive criticisms have been showered upon Flagstaff—suggestions of instrumental defects, of diplopic vision, of optical interference, of obscure physiological laws seemingly devised by Providence for the deception of planet-observers, of hypnotic suggestion. All, except perhaps the last, have been received seriously if not patiently; have been tested

* Kipling, 'Captains Courageous.'

in ingenious ways, killed to the satisfaction of Mr. Lowell and his assistants; and the possibility of self-deception has on every occasion been repudiated in the lively fashion which Mr. Lowell follows with his critics:

'That they are straight is certain—a statement I make after having seen them, instead of before doing so, as is the case with the gifted objectors';

'That an experienced observer should not know his own business is preposterous. One may or may not believe that the undevout astronomer is mad, but that the perpetually unfocused one would be is beyond debate.'

While the controversy has been carried on in Journals and Proceedings, the serious publication of the work of the Lowell Observatory has been made in three splendid volumes of *Annals*, and, more lately, in a series of *Bulletins*. The *Annals* are superbly illustrated with hundreds of drawings by Mr. Lowell and his assistants. The observation notes are full of precise and sober detail. There is a careful record of the many experiments that were made to guard against error, to make sure that the recorded detail was within the limits of possible detection. Independent discussion of the drawings by different people gave maps of the planet that were substantially the same, and that greatly extended, but hardly contradicted in any important point, the earlier work of Schiaparelli. It is impossible to refuse to this work the most serious consideration, and almost impossible to believe that the representations of the planet's surface so beautifully produced are not correct.

For a long time there was, indeed, much scepticism as to the reality of the famous canals upon Mars. No one but Schiaparelli saw them for some years. Then gradually other observers confirmed his results. That there can be any doubt about the existence of markings which are drawn as conspicuous as the hands upon the face of a clock may seem strange to those who are not familiar with telescopic work; they forget that the astronomer suffers always from the disadvantage that he is sunk at the bottom of a perpetually troubled ocean of air. Every owner of a telescope in the pleasant, low-lying, hospitable lands where telescopes are most often to be found, knows that if a friend asks to see Mars, he had better be refused. Mars seen at random by the inexperienced, Mars even seen with all precautions by a trained observer, is apt to be a very disappointing sight. You can see the polar caps and the broad dark so-called seas, but of the all-important finer detail there is generally no trace to be seen. It is lost in the perpetual surge

and tremor of the image produced by the waves of unequally heated air passing between the observer and his object.

Mr. Lowell gives us a good account of how the canals are seen :

'When a fairly acute-eyed observer sets himself to scan the telescopic disk of the planet in steady air, he will, after noting the dazzling contour of the white polar cap, and the sharp outlines of the blue green seas, of a sudden be made aware of a vision as of a thread stretched somewhere from the blue green across the orange areas of the disk. Gone as quickly as it came, he will instinctively doubt his own eyesight, and credit to illusion what can so unaccountably disappear. Gaze as hard as he will, no power of his can recall it, when, with the same startling abruptness, the thing stands before his eyes again. Convinced, after three or four such showings, that the vision is real, he will still be left wondering what and where it was. For so short and sudden are its apparitions that the locating of it is dubiously hard. It is gone each time before he has got its bearings.

'By persistent watch, however, for the best instants of definition, backed by the knowledge of what he is to see, he will find its coming more frequent, more certain, and more detailed. At last some particularly propitious moment will disclose its relation to well-known points and its position be assured. First one such thread and then another will make its presence evident; and then he will note that each always appears in place. Repetition *in situ* will convince him that these strange visitants are as real as the main markings, and are as permanent as they.

'Such is the experience every observer of them has had; and success depends upon the acuteness of the observer's eye and upon the persistence with which he watches for the best moments in the steadiest air.'

No observer can refuse to admit the justice of this statement —everything depends on waiting for the best moments in the steadiest air. And how many men have had an opportunity of doing so? W. H. Pickering at Arequipa, and afterwards with Mr. Lowell at Flagstaff; Barnard and Schaeberle at Lick: these are almost the only men who have studied the planet under conditions which are comparable with those of Mr. Lowell and his staff. Schaeberle partially, Pickering completely, confirm Mr. Lowell's observations of the planet. Barnard dissents; he has never seen anything like a canal, and that is one of the most curious things in the whole history of the planet. Yet we can hardly allow one negative result, however conspicuous, to outweigh many positive when we come to balance the evidence for or against the existence of the canals. Within the last ten years such astronomical opinion as dissented at first has been, in the main, converted, and almost the only unbelievers now

are the sect who profess what Mr. Lowell gaily calls 'the Small 'Boy Theory from the ingenuous simplicity on which it rests.' The headquarters of this persuasion are in the neighbourhood of Greenwich; its tenets are that the canals are an illusion, due to a supposed tendency of the eye to interpret a mass of confused detail at the limit of vision as a set of straight lines.

It seems to us that Mr. Lowell has a very fair answer to this school of objectors:

'Because some boys from the Greenwich (Reform or) Charity School, set to copy a canal-expurgated picture of the planet, themselves supplied the lines which had been preceptorily left out, the Martian canals have been denied existence; which is like saying that because a man may see stars without scanning the heavens, therefore those in the sky do not exist. . . . When Flammarion retried the experiment with French school boys, and even inserted spaced dots for the canals in the copy, not a boy of them drew an illusory line.

'The fact is, that this is one of those deceptive half truths which are so much more deleterious than an unmitigated mistake. Under certain circumstances it is quite possible to perceive illusory lines, due either to shadings otherwise unmarked, and thus synthesized, or to immediately precedent retinal impressions transferred to places where they do not belong by rapid motion of the eye. . . . But these effects are produced only at the limit of vision. . . . The Martian canals when well seen are not at the limit of vision, but well within that boundary of doubt; so that the premise upon which the whole theory rests gives way.'

We believe, then, that Mr. Lowell's observations of Mars will, if not now, at least very soon be accepted universally as by far the most complete representation of the surface of the planet, and that the Annals of his observatory will take rank as a magnificent contribution to our knowledge of the most interesting planet of the solar system. But, true to his first ideal, Mr. Lowell is not content with discovering new facts. He will always be seeing in them fresh proofs of his theory that Mars is inhabited by intelligent beings, who have constructed the canal system to irrigate their land with water from the melting of the polar snows. Twice he has challenged the world to accept his theory. On the first occasion it was difficult to treat it very seriously; his prepossession was too evident, his acquaintance with the planet of too short duration to compel acceptance of his ideas. But after eleven years of serious and most arduous work, he repeats the challenge in the recent book, 'Mars and its Canals,' now under notice, and it is necessary to give his argument most careful consideration.

Yet the style in which Mr. Lowell's arguments are presented

makes it very difficult to give them the deliberate consideration which they need. The reader is not allowed to think for himself. He is told what is the next point to be established, is introduced at once to 'phenomena so startlingly suggestive of this very 'thing as to seem its uncanny presentment,'* and is hustled away before he has had time to notice whether or no the cart is before the horse.

'If, now, we turn our inquiry to Mars, we shall be fairly startled at what its disk discloses. For we find ourselves confronted in the canals and oases by precisely the appearances *a priori* reasoning proves should show were the planet inhabited. Our abstract prognostications have taken concrete form. Here in these rectilineal lines and rounded spots we have spread out our centres of effort and our lines of communication. For the oases are clearly ganglia to which the canals play the part of nerves. The strange geometricism which proves inexplicable on any other hypothesis now shows itself of the essence of the solution. The appearance of artificiality cast up at the phenomena in disproof vindicates itself as the vital point in the whole matter.'

The geometrical character of the canals demonstrates the ingenuity of the inhabitant, who explains in his turn the geometrical character of the canals. In fact

> 'The dust of an earthy to-day
> Is the earth of a dusty to-morrow,'

or, as Mr. Lowell says in a finely deranged metaphor: 'That 'the point of departure should thus prove of twofold import-'ance, speeding the observer on his journey and furnishing him 'with a *vade mecum* on arrival, is as curious as opportune.'

If, then, we are resolved to form a deliberate opinion upon the evidence, it is absolutely necessary that we shut our ears to the blandishment of Mr. Lowell's running commentary, decline to be impressed by his hard words, as 'thaumaturgy' and 'teleologic,' refuse 'to find proof of concomitance, cogent 'because congenital,' and hesitate where we will, even if 'not 'to complete our syllogism would be to flaunt a lack of logic in 'nature's face.'

The plain tale of what is seen upon Mars is singularly impressive. At first sight the planet seems to be not so different from our own world that we need refuse to admit the possibility that life like our own might exist there. Mars is smaller than the Earth, yet not so small that there need be any difficulty in imagining living creatures proportioned to the feebler effects of

* We quote, for the moment, from his earlier book:

gravity. Mars has an atmosphere, thinner indeed than our own, and much less encumbered with cloud, but yet not so thin as to seem unable to support beings whose lungs were suitably adapted. Mars has polar caps, which grow in the winter and melt in the summer, and testify to a circulation of what we may for the present call moisture in its air. The surface of Mars is marked with light and dark; and thirty years ago it seemed not unreasonable to speak of the lighter, ruddy areas as land, and the darker areas as seas. Mars is further from the Sun than the Earth, and presumably colder, yet the melting of the polar caps in summer, and the almost permanent absence of snow from the equatorial regions, suggested that the temperature was at any rate above freezing point. It was not so very much more difficult to imagine that a modified man might live upon Mars than to understand how the same man can march without much damage from the sweltering heat of Calcutta over the terrible passes into Tibet.

It is therefore not a little singular that the first step towards a proof of the theory that intelligent beings live in Mars was to show that Mars is very much less like the Earth than had been supposed.

The dark markings may no longer be regarded as seas. This important fact was detected by Barnard and Pickering in 1892 and fully established by Lowell and Douglass in 1894. The supposed seas are crossed by canals, which is destructive to the character of the sea, whatever may be thought of the canal. Many attempts have been made to see the reflection of the Sun in a Martian sea, and they have always failed. The explanation of the failure is now, of course, of the simplest—the dark areas are not sea but land—a land coloured dark for some reason, which may be vegetation, but nevertheless a land which shows the same complex system of canals and crossing points as does the bright orange-coloured part of the planet.

The proof that the dark areas are not seas is probably the strongest observational point that Mr. Lowell has made. For if there are no seas the supposed analogy with the Earth vanishes, and we have to consider a land constituted in a very strange way. Why should our Earth have four-fifths of its surface covered with oceans, Mars have very little, if any, area of open water, and the Moon no trace whatever of water upon its surface? The natural view to take is that, by an accident of the process, whatever it may have been, by which they were formed, the Earth had much water given it and the Moon none; which is not what one might have expected if it is true that the Earth and the Moon had a common origin and separated from one

another comparatively late. So that we are not altogether surprised to find that there are people who contend that the Moon was not made dry and waterless; but that she has lost the oceans which she once had; and what is more, that all planetary bodies tend to lose their water, the smallest first. Upon this theory the Moon has quite dried up; Mars, which is twice the diameter of the Moon, has reached a very dry stage; our Earth, which is twice the diameter of Mars, has still abundant water, but is nevertheless in process of losing it.

Now, if one inquires how such a process might go on, one meets with two conflicting explanations: there is one school that contends that the waters of a planet are gradually absorbed into its interior, locked up in the formation of the hydrated rocks, and withdrawn from its surface, so that each planet in turn would reach a stage when surface water was scarce, though existent; Mr. Lowell belongs to this school. There is another school that pins its faith on the escape of gases from planetary atmospheres, and argues that any water vapour which may have existed in the Martian atmosphere must long ago have escaped into space.

A gas which is sufficiently light must escape at the top of an atmosphere whenever any of its molecules, constantly colliding and borrowing speed one from another, contrive to go quick enough to get away from the planet's gravitational pull. The theory of such a process has been very much debated within the last ten years.

Up to a certain point physicists are agreed upon this matter. It is certain that molecules of the lighter gases, hydrogen and helium, must be escaping at the top of our atmosphere, and getting away altogether from the controlling attraction of the Earth. But the question remains, how frequently does this happen? What proportion of the total amount of a certain gas in a planet's atmosphere can escape every year? And here it seems that the mathematical theory of gases fails to give a definite answer. On the one hand, it is contended that the process is an effective process; on the other, that it may well be so slow that its effect during the whole lifetime of a world is almost insignificant. Between these opposite conclusions, neither of which, it seems, can be established with any approach to an accurate numerical expression, we are left for the present uncertain. We are not sure that the lighter gases are escaping from the Earth in appreciable quantity year by year; still less are we sure that water vapour, which is able theoretically to escape from the atmosphere of Mars, is actually doing so in such quantities that the planet has thereby been rendered almost

waterless. We cannot, therefore, agree with Dr. Wallace when he argues against the existence of the Martian canals on the ground that water to fill them cannot exist on the planet, since it must have all escaped from the atmosphere into space.

Granted, then, that water may exist upon the surface and in the atmosphere of the planet, but that all observers agree that it is comparatively scarce there, we have now to ask ourselves the question, has Mars always had very little water, or did it once possess oceans that have disappeared, not by escape into space but by absorption into the interior? What evidence is there for the idea which Mr. Lowell puts forward, that planets lose their water by absorption; that both the Earth and Mars are gradually drying up; and that Mars has already consumed internally the oceans which made it once a pleasantly tempered well-watered world like our own?

If we look for this evidence first in Mr. Lowell's book we find it set out with that air of plausible inevitability so characteristic of his treatment of the whole problem. He finds an illuminating coincidence in the fact that the desert Mars can be studied only in the suggestive surroundings of high and dry and desert places of the Earth.

'Besides their immediate use as observing stations, these desert belts [of the Earth] possess mediate interest on their own account in a branch of the very study their cloudlessness helps to promote, the branch here considered, the study of the planet Mars. They help explain what they permit to be visible. . . . They are symptomatic of the passing of a terraqueous globe into a purely terrestrial one. Desertism, the state into which every planetary body must eventually come and for which, therefore, it becomes necessary to coin a word, has there made its appearance upon the Earth.'

There are indeed regions of the Earth where 'desertism' has set in. His description shows that the region of the San Francisco peaks is one. There are others that might well have been cited in support—parts of Lower Egypt that were fertile in Biblical times are now desert Lake; Chad is fast drying up; in Central Asia Dr. Sven Hedin has found the ruins of great cities lying half buried in desert sand. But the point which seems to have escaped the notice of Mr. Lowell is this, that desertism may very well be transitory instead of permanent. In many places it has established itself within historic times, rapidly, but not always capriciously; sometimes the reason is historic also. In Egypt, for example, the Mahometan conquest laid waste a large fertile country, and much of it went back to desert. The cause was not a secular tendency of the Earth, but a temporary interference with the cultivation of the land,

which nowadays is being reclaimed. The cause of desertism may sometimes be political, therefore, and subject to the ebb and flow of politics. But when, as in the case of Lake Chad, no political reason can be found, there is no need to assume that the result is permanent. The action now going on is too rapid for a secular action; the effect may very well be roughly periodic. At any rate, we have in England plenty of evidence to show that desertism is not necessarily a progressive state. In Triassic times England itself was a desert, as the sand-blasted granite boulders of Charnwood Forest attest; but the phase has passed.

Geologists do not admit Mr. Lowell's fundamental theorem, that planets tend to dry up. The life of our Earth may have reached its first striking developements in the sea, but it is not necessary to suppose that the sea was then more extensive than to-day; and that it was a shrinkage of the ocean that caused the transfer of the more enterprising forms of life to the land—the mere fact of enterprise may account for it very well.

We find no reason, therefore, for believing that Mars is drying up; it is at least equally likely that Mars was always a badly watered planet. And it seems, indeed, that if one wishes to suppose that the canal-like features of the planet Mars are water-channels, one should be chary of laying too much stress upon a supposed absorption of the oceans into the interior. For there does not seem to be any reason why the process should stop at the critical point when the oceans had been absorbed, and should allow time for the construction and use of a canal system of enormous extent, capable of making a very little water go a very long way without ruinous loss by soakage and evaporation. The loss by evaporation from the canal surface is reckoned by Dr. Wallace as one of the chief objections to a canal irrigation system upon Mars. It appears to us that the loss by soakage all over the irrigated country would be much more important, because, on the very hypothesis of the drying up, that loss would be in great part irrecoverable. We cannot, therefore, agree with Mr. Lowell that the inhabitants of a planet which was drying up would be likely to find a fleeting salvation in canal irrigation. Their planet would have a fundamental defect in its constitution that no conservation of rainfall or snowfall could overcome. A fraction would be lost to the surface each year, and the case would be essentially hopeless.

Let us note, however, that the difficulty in which we now find ourselves is a difficulty engendered, in part at least, by Mr. Lowell's desire to show that his theory is so natural and inevitable that an acute mind finds in the observations only a confirmation of what should have been obvious from first principles.

We are not in reality required to accept as axiomatic the idea that planets are drying up. But we may very well admit that Mars is a dry world without supposing that it is getting drier; and we may even imagine that it has inhabitants who have found it necessary or convenient to irrigate, without postulating as inevitable the sequence of events which starts with a population in luxury on a well-watered planet, unintelligent and unenterprising, and ends with the descendants of those people compelled to sharpen their wits, to fight against the growing unkindness of nature. We may, in fact, examine Mr. Lowell's scheme of Martian irrigation upon its merits.

The first essential of an irrigation scheme is evidently a good supply of water, and on Mars the source is hard to find, unless it be in the polar caps. Clouds, even of the thinnest, are rare. The evidence is all against a sufficient rainfall. But a polar cap forms in each winter, and disappears each spring, and that is the only sign that we can see of a circulation of moisture in the Martian atmosphere—whence the idea that a water supply must be drawn from the melting of polar snows. It does not appear, however, that any attempt has been made to inquire why this peculiar form of circulation should exist upon Mars. So far as we can see, Mr. Lowell does not try to explain why moisture evaporated from the soil and from vegetation at the equator should be transferred to the poles before it is precipitated, and in the absence of such an explanation we may be allowed to doubt whether any such effective circulation exists—effective in the sense that it is capable of taking up all the water vapour evaporated in the equatorial regions either by canals or by vegetation; of carrying it to the poles without losing a noticeable amount by precipitation *en route*; of carrying it, moreover, invisibly, and not in the form of cloud; and finally of depositing it all in the polar cap so systematically and so completely that the melting of the polar cap in spring will give back the whole of the water required for the support of vegetation in summer over the cultivated strips of a hemisphere.

It is a well-observed fact that the polar caps form late in the winter and disappear quickly—sometimes completely—in the spring. They have all the appearance of hoar frost or snow, and we do not think that there is any need to do more than admire the suggestion of those who, having disposed of the water vapour on Mars by escape into space, suppose that the polar caps are made of frozen carbonic acid gas. But we do believe that it is more consistent with the observed facts to suppose that upon Mars the circulation of moisture in the atmosphere is altogether small, and the precipitation slight in the

polar regions as in the equatorial, than it is to suppose that the whole water supply of the planet is carried from the equator to the poles by some process whose theory is altogether unknown, and there completely precipitated as snow.

The apparent neglect by Mr. Lowell of these rather obvious considerations leaves us in a difficulty, for we shall find it hard to give our attention to the details of an irrigation system, so long as we have something more than a suspicion that there is no water with which to irrigate. In this respect the phenomena which accompany the melting of the polar cap do not help us very much. As the white cap disappears it is surrounded by a dark ring, easily observable and well known. It may be water from the melting snow, but on the other hand it may be vegetation supported by the melting, and observation can scarcely decide between the two. If we inquire whether it is likely that a burst of vegetation would immediately follow the melting of the snow, we find it hard to decide from our experience upon Earth. In the Alps, under a brilliant spring sun, the grass and the flowers start into growth before the snow has gone; further north, in Russia, where the spring sun is less powerful, a period of bareness succeeds the white snow. The regions around the poles of Mars must be more like Russia than like the Alps, but we can scarcely venture to draw conclusions from that fact as to the probable behaviour of an unknown vegetation in an unknown climate. Still another question, then, must be left open, and it seems that if we are not disposed to share Mr. Lowell's confident optimism, we shall start upon our examination of his canals in a very unformed state of mind, without settled convictions regarding any of the fundamentals.

The appearance of the canals is consequent upon the melting of the polar cap. In winter they are invisible. In spring they begin to appear after the formation of the dark zone about the melting snow. Confined at first to the regions adjacent to this zone, they gradually extend equator-wards, until by midsummer a 'wave of seasonal change' has swept down from the pole to the equator, *and beyond.* This fact of the successive appearance of the canals seems to be fully established by the observations made at Flagstaff. Some influence passes down with the advent of summer along predetermined straight lines, and it is easy to see here the germ of the irrigation theory. Indeed, it is difficult to suggest a cause other than vegetation to account for the progressive change of colour. Admit vegetation, and one may admit that the arrangement of vegetation in straight strips has an appearance of artificiality. Accept the order of appearance, and one is compelled to believe, either that some

material cause of quickening vegetation has passed down from the pole, or, as an alternative, that upon a world like Mars spring comes first in the north and travels southward, in a way exactly opposite to that which we know upon the Earth. An inversion of the order of nature between two neighbouring worlds is not an easy thing to imagine. It is certainly no more difficult to adopt as a working hypothesis the idea of a material influence coming from the pole. Always remembering, then, that there is very grave doubt about the adequacy of the water supply, we may be prepared to agree with Mr. Lowell, that the observed phenomena are, at first sight, those which would be produced by an irrigation system. The idea is plausible; let us follow it up, and see how it works.

If we are to judge the canals on their apparent merits as a system of irrigation channels, we must try first of all to form an idea of the system which would seem most suited to a planet placed as Mars is placed in the solar system. And as we have exceedingly little positive knowledge of the physical condition of that planet's surface, we can do little more than imagine what might be done upon our own Earth if its conditions were modified in the direction of those which probably exist upon Mars. The question of the probable temperature of the surface of Mars is a very difficult one to answer. We shall have a later occasion to discuss rival opinions in some detail. For the present it is enough to say that Mars receives less heat from the Sun than does the Earth, and its atmosphere is less dense. Both these conditions make for greater cold. They are not appreciably modified by the length of the Martian day, which is only some thirty-seven minutes longer than ours. But the greater length of the Martian year, and the greater disproportion between the lengths of summer and winter which arises from the greater eccentricity of Mars' orbit, must tend to exaggerate the difference between the summer and winter temperature, especially in the planet's northern hemisphere, which enjoys a long summer and a short winter. How far this cause can go towards making at least the northern summer reasonably warm is hard to say, but it is probably safe to suppose that the temperature is not so high as that found upon the Earth, while it is almost certainly above the freezing point of water for a large part of the year. We may suppose ourselves, then, set the problem of how to irrigate a world somewhat, but not excessively, colder than our Earth.

As our water supply is deficient, we shall take care to use it to the best advantage, running our canals to the most favoured and fertile spots which we shall naturally have chosen in palmier

days for our settlements. We shall have to select the alignments of our canals very carefully, to follow the contours of the land, and we shall make every effort to economise in our immense task by restricting the irrigated area within the narrowest limit which will support our population. The shape which our scheme will take will depend principally upon two conditions, the relative fertility and the relative elevation of different parts of our country. But we certainly shall not expect to be able to construct our main canals upon what may be called the Roman Road principle, straight over whatever hills and dales there may be. Neither shall we expect to find that the country is so uniformly fertile that we can irrigate profitably strips of nearly uniform width on each side of each canal. Above all, we shall avoid wasting water upon those parts of the country which have already a fairly sufficient natural supply of their own.

These labours will change the face of the country. In spring larger tracts than before will turn from brown to green, deepen in colour as the summer proceeds, and revert to brown on the approach of winter as the crops are gathered and the leaves fall. The face of the country will have changed, but will these highly organised intelligent labours have made it take on a look so artificial that the artificiality is by far the most conspicuous thing about it? Our limited experience suggests the exact contrary. Our operations will be beset on every side with natural difficulties. Common sense will suggest that we conform as far as possible to the courses which nature has suggested. We shall supplement rather than supersede the operations which nature undertakes under happier circumstances, and shall try to avoid the fate of the man who wrote 'that he had constructed an eel trap out of pure theory, and it 'was a perfect failure.'

This anticipation of the way in which we should proceed to irrigate is surely reasonable. Yet compare it with the account which Mr. Lowell gives of the Martian canals.

'So dominant in its mien is the pencil-like directness of the canals as to be the trait that primarily strikes an unprejudiced observer who beholds this astounding system of lines under favourable definition for the first time, and its impressiveness only grows on him with study of the phenomena. That they suggested rule and compass Schiaparelli said of them long ago, without committing himself as to what they were. In perception the great observer was, as usual, quite right; and the better they are seen the more they justify the statement. Punctilious in their precision, they outdo in method all attempts of freehand drawing to copy them. Often has the writer tried to represent the regularity he saw, only

to draw and redraw his line in vain. Nothing short of ruling them could have reproduced what the telescope revealed. Strange as their depiction may look in the drawings, the originals look stranger still. Indeed, that they should look unnatural when properly depicted is not unnatural if they are so in fact. For it is the geodetic precision which the lines exhibit that instantly stamps them to consciousness as artificial. The inference is so forthright as to be shared by those who have not seen them to the extent of instant denial of their objectivity. Drawings of them look too strange to be true. So scepticism imputes to the draughtsman their artificial fashioning, not realising that by doing so it bears unconscious witness to their character. For in order to disprove the deduction it is driven to deny the fact. Now, the fact can look after itself and will be recognised in time. For that the lines are as I have stated is beyond doubt. . . . When one considers that these lines run for thousands of miles in an unswerving direction, as far relatively as from London to Bombay, and as far actually as from Boston to San Francisco, the inadequacy of material explanation becomes glaring.'

The eloquence of Mr. Lowell's account of their artificiality is convincing—the Martian canals are not in the least like any system of irrigation which we could imagine ourselves constructing upon a world where we were trammelled with natural restrictions. We seem thereby to be cut off from any possibility of effective criticism of them as works either of art or of nature, for nothing even remotely resembling these exists in our world. We have just one example of a long narrow strip of irrigation—the Nile valley—which might give to an observer upon Venus something of the effect of a Martian canal. The effect of the annual flood may very well make itself seen in a general change of colour visible so far away as Venus. But in the Nile Valley the straightness is natural, the narrowness of the fertile strip is natural; and the difference between the old natural and the new artificially controlled irrigation is principally this, that the irrigation department can store water behind its dams, and supply it at an unnatural time, to allow two crops a year, or to make it possible to grow valuable cotton in place of rice. The people of Venus would see the Nile valley grow green or keep green out of season; but upon the broad features of the country the artificiality of its water supply would have very little seeming effect.

If our view of the matter is correct, Mr. Lowell has altogether overdone his insistence upon the artificiality. He has drawn us a fine picture of the extraordinarily hard and fast geometry of the canals, and challenges us to deny that they have an extremely unnatural look. We admit it. Very well, he says,

that means that they are artificial, and the circumstances point very clearly to their purpose—they are irrigation canals. The crux of the argument lies in the assumption, which Mr. Lowell makes without comment, that an irrigation system would of necessity present such a highly artificial appearance. If we can deny this successfully, the whole argument falls to pieces.

We will make the experiment. We deny that an irrigation system would probably, or even within reasonable possibility, present the peculiar geometrical features of the Martian canals, and we base our denial upon two principal grounds. The first has been examined already. The natural features of the planet —apart from the canals—the old well-known detail that was supposed to be land and sea, has nothing particularly geometrical about it. And the proof that the 'seas' are no seas, but probably regions better watered than the reddish deserts, does not affect our argument. It is more reasonable to suppose that an irrigation system would be so blended with the natural topography of the planet that artificiality was not its most striking characteristic, rather than to imagine it carried out on the peculiarly artificial system which we must now discuss; though we may in passing admit that the precise degree of artificiality must depend upon the length to which Martian engineers may have been compelled to go.

Our second point may be stated without any such qualification—the geometry of the canals is not reasonably artificial. No explanation whatever has been given by Mr. Lowell of the most characteristic feature of his canal system—the precise linear arrangement of the crossing points, the oases, as he calls them. 'The spots make common termini for all the canals of a 'given neighbourhood. In other words, canals converge to the 'places occupied by the spots and do not cross haphazard 'according to the laws of chance. Only one instance exists where 'a spot fails to gather to itself the whole sheaf of canals, and 'even there it collects all but two.' And again, 'The con-'nexion of the canals with the oases is no less tell-tale of intent. 'The spots are found only at junctions, clearly the seal and 'sanction of such rendezvous. Their relation to the canals 'that enter them bespeaks method and design.' These spots are the crucial points of the system. If there is any truth in the irrigation theory, they must be the centres of agricultural activity, if not the centres of population; the places where irrigation is most valuable, where it pays best to expend great labour. But why, then, do we find these spots strung like beads upon strings: not upon single strings only, but on strings that cut across and across, and all the while preserve their straightness.

This is artificiality untrammelled by any natural limitations, meaningless so far as we are judges of meaning, impossible to our conception of what is possible in the arrangement of a world. Imagine Europe irrigated upon this plan. Paris, Cologne, Berlin, Warsaw, and Moscow lie on a perfectly straight canal, with irrigation extending ten or fifteen miles on each side, of uniform width, and a circular patch fifty or sixty miles across centred on each city. A second straight canal, with the same features, includes Paris, Berne, Munich, Budapesth, and Odessa; a third finds Bordeaux, Munich, Warsaw exactly in a line; a fourth perfectly straight canal runs *via* Hamburg, Berlin, Budapesth, Belgrade; and so on. To say that the canals of Mars are drawn with all the precision of the rays of a geodetic triangulation is a complete understatement of the case; the primary points of a survey are not found four and five together upon a straight line. We can find nothing either natural or reasonably artificial in this linear arrangement of the spots. We do not see, therefore, how it is possible to accept the system as a proof of intelligent activity—unless, indeed, we are content to accept also the ingenious suggestion that we find it difficult only because the Martians are more intelligent than we are.

It is relatively easy to form an opinion whether a particular kind of abnormal artificiality proves that Mars is peopled by an intelligent race of engineers. But it is far more difficult to weigh the arguments for or against the abstract habitability of the planet. True to his belief that our Earth alone in the universe has been the scene of the evolution of life, Dr. Wallace tries to rebut Mr. Lowell's arguments upon more general grounds: that water cannot exist in the Martian atmosphere, and that the temperature of the planet must be far below freezing point.

To the first point we have already referred. There are theoretical grounds for believing that the molecules of water vapour may escape into space from the top of Mars' atmosphere. There is great difficulty in judging whether such a process could be effective in getting rid of more than a minute proportion of the total water vapour present. We are very much in need, then, of a direct proof or disproof of the actual presence of water, such as the spectroscope might supply. But the observations required are of great delicacy, and the negative results which have been obtained can scarcely be taken as definite disproof; they show only that water vapour is not present in quantities sufficient to cause a marked absorption.

The question of the probable temperature of Mars is even more difficult, involving points of theory about which there is some difference of opinion. Mr. Lowell has published elaborate

papers to prove that the climate of Mars is temperate, to which Professor Poynting replies that the radiation of the atmosphere has been neglected, and that when it is taken into account the results are entirely changed, much to the disadvantage of Mars. Dr. Wallace argues that on the top of a very high mountain in the tropics the cold is great, and that the rarity of the air is responsible. On Mars the air is apparently much rarer than it is on any accessible mountain top of the Earth, while the heat received from the Sun is less, whence it would appear that the cold must be greater. But it is very difficult to be certain that no factor in the complicated theory has been neglected, and equally difficult to appraise the value of an apparently straightforward argument. To some extent it is still a matter of taste, whether one should believe that the melting of Mars' polar caps proves a defect in the theory, or that the theory proves that the polar caps are not made of snow.

It seems, then, that there are two criteria for the possibility of life on Mars: the existence of water, and a sufficient temperature. On both matters the opinion of astronomers and physicists is much divided, so that we cannot say with any certainty whether a world otherwise not unsuitable is actually in those two fundamental respects able to support human beings anything like ourselves. And we have found ourselves quite unable to accept Mr. Lowell's view that the design of the canals is any evidence of intelligence: a conservative view of the matter lies entirely on the other side. So far as proof positive of the existence of life or even of habitability is concerned, the recent strenuous work of the astronomers of Flagstaff, tempered by the acumen of many critics, seems to leave us very much where we were before.

The great popular interest in the planet Mars has arisen, of course, from the expectation of finding life, and the excitement of this possibility or the disappointment of its non-realisation may tend to obscure the very real interest of the problems that remain when the question of life is put on one side. There are fascinating points of astronomical technique for discussion, and matters of theory which touch the most fundamental of our views as to the evolution of the solar system. We have space to discuss only two, and we will select the photography of the canals for the first, and Dr. Wallace's opposition theory of canal formation for the second.

When it was announced last summer that the canals had been photographed at Flagstaff, and the gold medal of the Royal Photographic Society was awarded to prints which were certainly

wonderful, but as certainly did not show the canals, the curiosity of celestial photographers was roused to a high pitch, which was scarcely damped by the accident of a reputable scientific journal publishing as photographs a set of what were very obviously drawings. One of the few branches of astronomy in which photography had made scarcely any progress was the delineation of fine planetary detail. In the patient accumulation of faint impulses of light the photographic plate is unrivalled; in power of resolution of fine detail it is greatly lacking, for a reason which Mr. Lowell expresses very well:

'Where illumination alone is concerned the camera works wonders; not so when it comes to a question of definition. Then by its speed and agility the eye steps into its place, for the atmosphere is not the void it could be wished, through which the light waves shoot at will. Pulsing athwart it are air-waves of condensation and rarefaction that now obstruct, now further, the passage of the ray. By the nimbleness of its action the eye cunningly contrives to catch the good moments among the poor and carry their message to the brain. The dry plate by its slowness is impotent to follow. To register anything, it must take the bad with the better to a complete confusion of detail. For the air-waves throw the image first to one place and then to another, to the blotting of both. . . .

'Of scant importance to the expert in such matters as Mars, there is a side of the subject in which service might be hoped of it: that of elementary exposition. Congenitally incapable of competing with the eye in discovery, the most that, by any possibility, could be looked for would be a recording of the coarser details after the fact.'

The Flagstaff photographs do rather more than come up to this modest estimate of their possibilities. They are surprisingly good representations of a very difficult object, and their success seems to be due to two improvements in technique. They were made with a colour screen carefully adapted to the chromatic correction of the telescope, so that the photographs were taken in precisely those rays which the objective brought to the most perfect focus—a method which is not precisely new, but which had not, we believe, been applied before to the photography of planets. And they were made with an attachment which allowed long series of exposures to be made at very short intervals of time. The reason for adopting this method is clear: the photographic plate is not intelligent, and cannot select the moments of steady seeing, as the eye does, discarding the far more numerous moments of bad seeing. But if one takes enough photographs, it is probable that some of them will happen to fall at times of good seeing, so that of many thousand photo-

graphs a few will be really good. Mr. Lowell reports that this somewhat heroic procedure has met with success; he has photographed the canals, even some of the double canals. As is only natural, however, the finest detail can be seen only on the original negatives. It is lost in the prints from those negatives; and unfortunately only paper prints have been sent across the Atlantic, so that astronomers upon this side are still unable to judge for themselves the precise degree of Mr. Lowell's success. Mr. W. H. Wesley, whose combination of artistic and astronomical gifts makes his judgement of great value, is satisfied that he can see, even upon the prints, three or four of the principal canals, but no more; and others have failed to see as much. We must suspend our judgement until Mr. Lowell finds it possible to submit a selection of his best negatives to independent examination; and meanwhile we may be permitted to reserve our opinion as to the reliance which may be placed upon enthusiastic statements in the press, claiming a complete corroboration of the visual observations—very much more than was anticipated by Mr. Lowell himself in the passage which we have quoted above.

In our judgement, however, photographic corroboration of the canal system is valuable, but not vital. We do not see how it is possible to deny the substantial truth of the strange geometrical arrangement which rests now upon so solid a basis of observation. On the contrary, we must accept the problem of explaining it as one of the most interesting of current astronomical questions. And whoever finds reason for declining to admit that it is obviously artificial may very well feel himself bound to speculate on a natural mode of origin. Several explanations of the crack or geological fault type have been suggested; but they are all open to the same objection that seems to wreck the hypothesis of artificiality. The lines cut straight across one another. We might imagine that the group of canals which radiate from a single centre were of the nature of the cracks which sometimes start from a centre of weakness in a highly strained shell. But if a second system of cracks was formed, it is almost impossible to believe that the second might cut straight across the first, for all experience of cracking goes directly against this idea. For this reason, if for no other, we find it impossible to accept the wonderful theory of the formation of Mars and his canals which Dr. Wallace presents to us in the concluding chapters of his book.

It is well known that for many years Sir Norman Lockyer has preached the meteoritic theory of the formation of planets and suns; and it is equally well known that his brother astronomers have been a little shy about accepting his new gospel.

Within the last few years Professors Moulton and Chamberlin, of Chicago, have elaborated an advance upon the meteoritic hypothesis, and produced the fantastic theory of 'planetesimals,' which has provoked no enthusiasm among astronomers, but has been a little more fortunate among geologists. We may quote, as does Dr. Wallace, a few lines from a recent geological address:

'The planetesimal theory is a development of the meteoritic theory, and presents it in an especially attractive guise. It regards meteorites as very sparsely distributed through space, and gravity as powerless to condense them into dense groups. So it assigns the parentage of the Solar System to a spiral nebula composed of planetisimals, and the planets as formed from knots in the nebula, where many planetesimals had been concentrated near the intersection of their orbits. These groups of meteorites, already as dense as a swarm of bees, were then packed closer by the influence of gravity, and the contracting mass was heated by the pressure, even above the normal melting point of the material, which was kept rigid by the weight of the outlying layers.'

We may admire the ingenuousness of those who, wishing to start with something more aboriginal than a fairly simple solar system, have hit upon that most dynamically complex and incomprehensible thing, a spiral nebula, for their protoplasm. But the theory of planetesimals is not as yet among the theories of dynamical astronomy which are accounted canonical. Only semi-popular accounts of it have been published, and it has never been subjected in detail to the scrutiny of keen-eyed mathematicians. So at present we are not even sure that it does not suffer from the disadvantage attributed not long ago to another theory, that 'it is very interesting, but contradicted by 'the laws of gravitation,' and we fear that Dr. Wallace was not well advised when he adopted it as 'the last word of science upon 'the subject of the origin of planets.'

His adaptation of the theory to the case of Mars is very curious. He supposes that Mars was formed by the gradual accretion of solid planetesimals, so slowly that the heat engendered by the impact of each little body was lost by radiation almost as soon as generated, so that the process produced a hard cold world of stones. Then there came along a dense mass of planetesimals that the cold planet captured very quickly, with the result that it accumulated a hot molten skin upon a cold interior. The skin cooled quickly and shrank and cracked, and so we have the canals. In recent years people have been very free with their hypotheses of capture, forgetful of the clear dynamical principles which show that the conditions for capture are altogether exceptional. We do not believe

that Dr. Wallace's exploitation of the planetesimal theory will stand the strain of examination by cold-blooded mathematicians. And he is a rash person who would start out to explain the evolution of the Martian canals from a spiral nebula, rather than admit the existence of any desired number of super-intelligent Martians.

We must conclude that neither author has succeeded in the task which he undertook. Mr. Lowell has failed to make us see, as he does, in his Martian canals any proof of the existence of intelligent constructive life upon the planet. Dr. Wallace has not been able, we believe, to add anything material to his favourite thesis that our Earth is the unique abode of life in the universe. Each has done something to produce the impression that the scientific man is as prone as the man in the street to adopt his conclusions first and fit the facts to them afterwards. The impression is not good for the credit of science, but happily there is no need for admitting that it is a just impression. Sober scientific opinion has always maintained an attitude of extreme reserve in the question of life upon Mars. One cannot expect that the newspapers will do the same, for as the American reporter said to an astronomer who protested that sensational discovery was not in his line: 'Sir! The public 'demands it.' The public, however, has opportunities for observing how the same facts assume different complexions when viewed through spectacles of opposite party colours, and it may also notice that there are two distinct ways of collecting your facts, prior to drawing the desired conclusions from them. You may collect new and most valuable information, and then partially discredit it in the eyes of the other side by regarding it always through spectacles of a particular colour. This has something in common with Mr. Lowell's method. Or you may search all the accumulations of knowledge and select those pieces, and those only, which are already of the right colour. This is Dr. Wallace's method.

Both the books under review are astronomical, yet they cannot be judged by the precise canons of the older astronomy, with its well-deserved character of most exact of all the sciences. In the year 2004 the planet Venus will be seen in transit across the disc of the sun; there is no more doubt about it than there is doubt that before these lines are published a partial eclipse of the sun will have been visible in England. The doctrine of astronomical infallibility must never be extended to those domains of speculation in which the laws of geometry do not occur, the laws of physics are enforced with some hesitation, and the laws of prudence and common sense do not always use their strong arm to keep order.