Art. VI. — "MAN'S PLACE IN THE UNIVERSE."

By Alfred Russell Wallace. Chapman and Hall. 1903.

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Part I.

SINCE it has been ascertained that the Earth which we inhabit is a planet revolving, like others, around the Sun, and that the Sun itself is a star, one among many thousands, there has been a natural disposition to wonder whether there exists in the various heavenly bodies life such as we know it on our own Earth. Many men have taken for granted that the planets are inhabited by beings more or less resembling ourselves: it is an idea that commends itself easily to persons who have merely a superficial acquaintance with astronomy; and it must be admitted that some scientific men, though perhaps with more caution and discrimination, have encouraged such an opinion. The increased knowledge, however, of the celestial bodies which has been obtained during the last fifty or sixty years, has greatly modified the tendency to indulge in these unreal speculations. No one who is aware of the physical constitution of the Sun, or of the present state of the surface of the Moon, would suppose that there are inhabitants in either one or the other: the same thing applies to some of the planets; and indeed as to all of them considerable doubt exists.

The very nature of the subject precludes, of course, any definite conclusion: we can but weigh the evidence, such as it is, in an uncertain balance, and be satisfied with precarious results. This caution should be always borne in mind if we would avoid false or hasty judgments in a matter so far transcending all human experience.

The work which stands at the head of my article is indeed a most able and interesting contribution to this vexed question. Dr. Wallace, after a long life devoted to biology and kindred studies, has made himself acquainted with modern astronomy, and has satisfied himself that this Earth is probably the only abode of life, at least of the higher type, in the whole universe. It will be for my readers to judge how far he makes out his case: indeed, to those who wish to master the subject, I warmly recommend the careful perusal of the work itself. The author had first published his views in magazine articles; and some able astronomers have since then criticised him in the *Fortnightly Review* and the scientific periodical called *Knowledge*. The present work, though apparently written with considerable rapidity, is a more guarded and elaborate statement of the ground of his convictions, and contains an answer to a few of the antagonistic criticisms.

Dr. Wallace alludes to some of the authors who have formerly dealt with the question at issue, and particularly the late Dr. Whewell, whose book, entitled a *Dialogue on the Plurality of Worlds*, takes a similar line to his own; and it may be mentioned in passing that a statement occurs in this work that Sir Isaac Newton argued at considerable length that the Sun was probably inhabited, which we may be very sure he would not have done if he had lived in the present age and had all the advantage derived from acquaintance with modern discoveries. Dr. Whewell's principal opponent was Sir David Brewster, whose work, it seems, appealed mainly to *a priori* considerations and religious prejudices, and maintained that the planets, being created such as they are—or, I should perhaps say, such as he imagined them to be: each for some special purpose, by the hand of God—must be inhabited, or some of them must be so; Venus, as being of about the same size as the

Earth, with years analogous to our own; and Jupiter, since he had four moons to give him light; and with regard to the double stars, "no person can believe that two suns could be placed in the heavens for no other purpose than to revolve round their common centre of gravity."

Dr. Wallace describes arguments of this sort as weak and fallacious rhetoric, as to which we may well agree with him; but it is very remarkable that scientific men, writing half a century ago, should have taken the religious ground as their stand-point, whether arguing rightly or falsely; whereas the tendency at the present day is to leave out all consideration of God, or to shrink from introducing the idea of His creative and directing Providence, except in the most cautious and guarded way.

Dr. Wallace mentions that the late Mr. Proctor, certainly a very able astronomer, in a work called *Other Worlds than ours* (written several years ago, but more recently than the two works above mentioned) took something resembling the same line as Sir David Brewster, and on much the same theological grounds. But in a second work, entitled *Our Place among Infinities*, published five years later and containing a chapter devoted to this subject, the same author gives his more matured views of this question, and argues in favour of the relative scarceness of inhabited worlds. He truly observes what a short time, comparatively speaking, in the history of this Earth, has been occupied by the existence of the higher kinds of organic life; what a vast period must have elapsed before the Earth was inhabitable at all; so that there is a considerable chance that the other planets in our system are not in that exact stage of their existence which would fit them for the habitation of life, or at least of highly developed life such as we are acquainted with here. But as regards the stars, though we do not know the conditions required for the formation of planetary systems around them, yet considering the immensity of the universe, there might be many worlds producing life as upon our own Earth.

The author of the work now before me explains that he is addressing it not merely to men of science, but to educated readers in general; and after giving a short account of the controversy on the plurality of inhabited worlds, devotes a large portion of his book to explaining the marvellous discoveries of what is termed the New Astronomy, dating as it does from about the middle of the nineteenth century; but he suggests in his preface that those who are acquainted with modern astronomy may omit this earlier part of the book, though I myself am disposed to advise all readers to look through it with as much attention as they can bestow. The controverted points are mostly reserved for the latter part of the work, and require more attention. I will endeavour to give in a compressed form some sketch of what our author tells us concerning the New Astronomy, though I fear that my readers will accuse me of dwelling on it at too great a length, and yet it is almost necessary for the due comprehension of the whole subject.

I may premise that the general opinion of the ancients, though with some exceptions, as also that of the middle ages, was that the Earth, a vast sphere, was suspended in the centre of the universe, and that the Sun and all the heavenly bodies revolved around it. This was held until the time of Copernicus, whose theory of the motions of the planets was so near an approximation to the truth that it actually gave the author's name to the system which recognised the Sun as the centre around which the planets, including the Earth, revolve; the system being still popularly called *Copernican*.

The work of Copernicus was favourably received, but does not seem to have made permanently such an impression as might have been expected—as, indeed, the violent opposition to Galileo shows to have been the case. But by this time something else had taken place which was destined to shatter the old system of astronomy, not indeed immediately, but slowly and surely—the invention of the telescope. This instrument was first turned upon the heavens by Galileo; but probably few, if indeed any, foresaw at the time how completely the telescope would revolutionise the pre-existing notions of astronomy.

Kepler was a contemporary of Galileo, and the publication of his three celebrated laws was a marked advance in the science. Copernicus had made the mistake, a most natural and excusable one, of supposing the planets to revolve around the sun in circles; Kepler discovered that they revolved in elliptical orbits, the Sun not being in the centre, but in one of the foci. It still remained, however, to find the key to the system, and to explain why these celestial motions proceeded in the order which was observed. Later on, towards the close of the seventeenth century, this was done principally by the great genius of Newton and the discovery of the law of universal gravitation. According to this law, all bodies attract each other directly in proportion to their combined masses, inversely as the square of their distance from each other. In the case of the Sun and a planet, strictly and scientifically speaking, neither exactly revolves around the other, but they both revolve around their common centre of gravity. True it is that with respect to the Sun and the Earth this centre of gravity is within the volume of the Sun, the mass of which is so enormously greater than that of the Earth; and though this be not so with all the planets, nevertheless, owing to the vast mass of the Sun, to which I have just alluded, the centre of gravity is always so near him that practically we may speak of all the planets in the Solar system as revolving around the great central luminary.

Dr. Whewell, in an eloquent passage in his *History of the Inductive Sciences*, after recounting the process by which the theory of universal gravitation was established under Newton's auspices, speaks of it as the greatest scientific discovery that had ever yet been made—so that astronomy was enabled by it to pass from boyhood to maturity. There is a great deal of truth in this; but it was some time before the discovery was fully and entirely accepted.

I do not propose on the present occasion to discuss the action of the Roman Congregations in the case of Galileo: I may however remark that the first relaxation of the anti-Copernican restriction was in 1757, during the pontificate of Benedict XIV., when a new Index was published in which was omitted the long-standing prohibition of books teaching the suspected doctrine. In the year 1820 a permission appears to have been given by the Holy Office for teaching the truth of the movement of the earth; and again in 1822, during the reign of Leo XII., a decree was issued declaring that the printing and publishing at Rome of works treating of the movement of the Earth and the immobility of the Sun was henceforth permitted.

To return however to the subject before us, we may remark that Newton's discovery was readily accepted in England, as might have been anticipated; and the old system of astronomy as taught by Ptolemy was displaced here, as indeed it was eventually everywhere.

In the early part of the nineteenth century astronomical science seemed in some sense to have come to a standstill: Adams and Le Verrier had certainly discovered the planet Neptune; but so far as any great development of the science was concerned, nothing had happened and nothing was expected.

Our author quotes Auguste Comte, the founder of the system of the Positivists, who wrote a popular work on astronomy in 1844, in which he states that since the stars are only accessible to us by night, we can know little more than their mere existence; that it was in vain that men had endeavoured to distinguish two astronomies, the one solar, the other sidereal; and that in the eyes of those for whom science consists of real laws and not of incoherent facts, the second exists only in name: to which he added that he was not afraid to assert that it would always be so.

Three years after the death of Comte, in 1860, the German physicist Kirchhoff discovered the method of spectrum analysis, resulting in a flood of light being thrown upon the nature of chemistry, both of the Sun and of the stars, enabling us to acquire that very knowledge which Comte had thought impossible, including the existence of numerous stars, otherwise invisible; the determining of stellar orbits, their rate of motion and their mass, at least approximately.

Here, however, some explanation is necessary. The property of a piece of glass, shaped like a prism, in dispersing the light of the sun and showing all the colours of the rainbow, had long been known. Light is believed to be due to the vibrations of ether, that invisible and mysterious substance, "which fills space at least as far as the remotest of the visible stars and nebulæ;" and these minute vibrations produce the phenomena of heat, light and colour. It has been found by experiment that the size and rate of vibration of the waves of ether vary considerably, those forming the red light (the least refracted) "having a wave length of about $\frac{1}{326000}$ of an inch, while the violet rays at the other end of the spectrum are only about half the length, or $\frac{1}{630000}$ of an inch. The rate at which the vibrations succeed each other is from 302 millions of millions per second for the extreme red rays to 737 millions of millions for those at the violet end of the spectrum." Such are the wonderful minuteness and rapidity of these heat and light waves, on which so much depends. Besides the *colours* of the spectrum, as shown by the prism, our author goes on to tell us that "very early in the nineteenth century a close examination showed that it was everywhere crossed by black lines of various thicknesses, sometimes single, sometimes grouped together." Accurate drawings and maps were made of these lines by several observers who, by combining a number of prisms, succeeded in producing a spectrum of considerable length (some feet long), so that "more than 3,000 of these dark lines were counted in it. But what they were and how they were caused remained a mystery till, in the year 1860, . . . Kirchhoff discovered the secret, and gave to chemists and astronomers a new and quite unexpected engine of research."

"It had already been observed," our author continues, "that the chemical elements and compounds, when heated to incandescence, produced spectra consisting of coloured lines or bands; . . . and it had also been noticed that some of these bands, especially the yellow band produced by sodium, corresponded in position with certain black lines in the solar spectrum. Kirchhoff's discovery consisted in showing that when the light from an incandescent body passes through the same substance in a state of vapour or gas, so much of the light is absorbed that the coloured lines or bands become black. The mystery of more than half a century was thus solved; and the thousands of black lines in the solar spectrum were shown to be caused by the light from the incandescent matter of the sun's surface passing through the heated gases or vapours immediately above it, and thereby having the bright coloured lines of their spectra changed by absorption to comparative blackness."

We ought to pay great attention to this explanation which I have just quoted, for it is the key to a great problem, the solution of which is the glory of the modern astronomy.

I may observe, by the way, that the above-mentioned is not the only instance of an object really bright appearing to be black—the spots in the Sun being a striking case, since they seem to us to be black on account of the extreme brilliancy of their surroundings. The chemists and physicists of the day lost no time in examining the spectra of the elements and comparing them with the dark lines of the solar spectrum, the result being that very many of the coloured bands in the former corresponded exactly with a group of dark lines in the spectrum of the Sun; and an inference was drawn, doubtless correctly, that a large number of terrestrial elements existed (in a very highly heated condition) in the Sun, among them being hydrogen, sodium, iron, copper and many others; also one supposed then to be peculiar to the Sun, though since discovered in a rare terrestrial mineral to which the name of Helium was given. The number of lines by which the elements were represented varied considerably, iron having more than 2,000, lead and potassium only one each.

It is surmised that the mysterious element radium exists in the Sun; but this will no doubt be more fully investigated.

An improvement was now introduced in the instrument of observation; diffraction-gratings (as they are termed), formed of a polished surface of hard metal, ruled with extremely fine lines, being substituted for glass prisms. It was found to be more easy in this way to obtain a large and well-defined spectrum. Then by means of telescopes with micrometers the wave-lengths of the different parts of the spectrum came to be accurately measured; and as these wave-lengths are so excessively minute, a still smaller unit of measurement was fixed upon, namely, the ten-millionth of a millimetre (technically termed "tenth meter"), equivalent in English measures to about the 250-millionth of an inch. "This excessively minute scale of wave-lengths . . . is of great importance. Having the wave-lengths of any two lines of a spectrum so determined, the space between them can be laid down on a diagram of any length, and all the lines that occur in any other spectrum between these two lines can be marked in their exact relative position."

The possession of such a powerful and delicate instrument made it possible to establish the science of Astrophysics, to which the popular name of New Astronomy has been given.

The next step, after the interpretation of the Sun's spectrum and the knowledge thereby gained of the substances existing in the Sun, was the discovery of the real nature of the stars. They had long been believed by astronomers to be suns, an opinion well justified by their great brilliancy notwithstanding their enormous distance—a distance so great that the whole diameter of the earth's orbit did not appear to cause a change of their relative positions; at least, such as could be readily detected. "The spectroscope at once proved the correctness of this opinion. As one after another was examined, they were found to exhibit spectra of the same general type as that of the sun—a band of colours crossed by dark lines." Those first examined showed that nine or ten of the elements already familiar to us existed in them.

It was soon found that the stars might be classed in three or four groups. One group contains, it is said, more than half the visible stars, and a still larger proportion of the most brilliant, such as Sirius, Vega, Regulus, Alpha Crucis. "They are characterised by a white or blueish light, rich in the ultra-violet rays, and their spectra are distinguished by the breadth and intensity of the four dark bands due to the absorption of hydrogen."

Another group, "to which Capella and Arcturus belong, is also very numerous, and forms the solar type of stars. Their light is of a yellowish colour, and their spectra are crossed throughout by innumerable fine dark lines." A third group consists of red and variable stars, characterized by fluted spectra. A last group, consisting of few and comparatively small stars, has also fluted spectra. These groups were first established by Father Secchi, S.J., in 1867. There is some uncertainty as to the interpretation of the different spectra, but there is little doubt that they correspond with differences of temperature and other differences in the various groups. Also we infer, as an unquestionable fact, that the stars are true suns, differing in their size and their stage of development, but all possessing a light-emitting surface, and absorptive atmospheres of various qualities.

There is, moreover, another application of the spectroscope—one, indeed, truly marvellous—that of measuring the rate of motion of any of the visible heavenly bodies in a direction either directly towards us or from us, however distant it may be. This depends on the wave-theory of light, and the principle is the same as that well-known in acoustics, where we find by experience that the pitch of any note sounded by a body rapidly approaching us is higher than that from the same body receding from us, the distances in each case being equal. The whistle of a railway engine is a good instance. In the case of a star, the colour of a particular part of the spectrum depends upon the rapidity with which the ethereal waves reach our eyes; so that the difference in this rapidity, when the source of light is receding from us, or on the other hand approaching to us, causes a slight shifting in the position of the coloured bands of the spectrum, and therefore of the dark lines—that is, of course, if there be a motion sufficient in amount to produce a perceptible shift. Sir William Huggins, in 1868, found, by means of a very powerful spectroscope, that a change of this nature did occur in the case of many stars and that their rate of motion towards us or away from us—the radial motion, as it is termed—could thus be calculated.

A remarkable result of this last-mentioned discovery is the fact that it has now become possible to determine the existence of invisible stars, that is to say, that though in binary systems, where two stars revolve around their common centre of gravity, both stars are generally visible, yet many are now known of which one star only is visible, while "the other is either non-luminous or is so close to its companion that they appear as a single star in the most powerful telescopes."

Some of the stars known as variable stars belong to this last-mentioned class, a very good example being Algol in the constellation Perseus, which changes its apparent magnitude in a few hours, owing to a dark companion of a size not much inferior to its own. The majority, however, of the double stars are both bright. They have separate spectra, discernable as such by the best spectroscopes, though, in many cases, no telescope shows them as more than one star. And, in fact, by the aid of this wonderful instrument not only double stars, but triple and multiple systems, have been discovered.

There is one other important result of spectrum analysis, which is the demonstration that true nebulæ exist, and that they are not all, as was once supposed, clusters of stars. There is reason to believe that they are the material out of which stars are formed and that, as our author expresses it, "in their forms, aggregations, and condensations, we can trace the very process of evolution of stars and suns." There are only one or two of these masses of gaseous or other matter visible to the naked eye; but many can be seen by the aid of a good instrument.

There remains one most important engine of research to be noticed, which has come into use in recent times, that of celestial photography. If a good camera is properly mounted so that an exposure of several hours can be made, stars can be photographed so minute in point of apparent magnitude as to be invisible even in the most powerful telescopes. Thus too, by the preservation of photographic plates, on which the spectra are self-recorded, the discovery of new variable and binary stars has been rendered possible. The number of stars visible to the unaided eye has been estimated by the American astronomer Pickering to be 5,333; but this calculation includes those slightly less than the sixth magnitude, some of which are barely visible without a telescope. Those which can be discerned with good instruments amount to at least 100 millions; and, indeed, some astronomers would say very many more.

Now, a very large proportion of the stars lie in that vast belt so well known even to superficial observers which we term the Milky Way, or Galaxy. As an important part of Dr. Wallace's argument is connected with this enormous aggregation of stars, he devotes a considerable space to the description of it, and introduces some long extracts from Sir John Herschell's *Outlines of Astronomy*, in which the subject is fully and minutely treated. These extracts are too long to be reproduced here; but I may say that the Milky Way follows the general course of a great circle around the heavens, that it is (as our author says) "extremely irregular in detail, sometimes being single, sometimes double, sending off occasional branches or offshoots, and also containing, in its very midst, dark rifts, spots, or patches, where the black background of almost starless sky can be seen through it."

It is to be observed that the Milky Way contains a large proportion of the brighter stars, twelve out of thirty-two brighter than the second magnitude and thirty-three out of ninety-nine brighter than the third magnitude, according to Mr. Grove's estimate. If we treat it as a great circle and count from its poles to the circle itself, we find at first a slowly increasing density of stars as we approach the Galaxy, and on reaching it the density arrives at its maximum.

The Pleiades are also mentioned as an instance of the aggregation of stars, the six visible to the naked eye being increased to hundreds by the use of a powerful telescope; while photographs, with an exposure of three hours, show more than two thousand.

Besides all these there are many clusters of stars, some globular, some irregular. "In the southern hemisphere there is a hazy star of about the fourth magnitude, Omega Centauri, which, with a good telescope, is seen to be a magnificent cluster, nearly two-thirds the diameter of the Moon." A good photograph shows more than 6,000 stars in it, and some observers believe that there are at least 10,000. There is also a very fine cluster in the northern hemisphere in the constellation Hercules. It appears that these star-clusters are thickly strewn over the entire course of the Milky Way and along its margin, while they are scattered at rare intervals elsewhere—with the exception of the Magellanic clouds (as they are called) in the southern hemisphere, where they are densely grouped.

The nebulæ, on the other hand, with the exception of a few of the larger and more irregular type, situated in or near the Milky Way, appear to avoid it, this being the case with the great majority of the smaller irresolvable nebulæ which, for the most part, are spread over the sky at a distance from it. Their forms are in many instances very curious, and different from each other ; some being ring-shaped, some spiral, some quite irregular. Several of them are termed planetary nebulæ, from their exhibiting a faint circular disc like that of a planet. Many have stars evidently forming part of them ; the greater portion, however, being minute cloudy specks, only visible with good telescopes. Nebulæ were formerly supposed to be star-clusters, such as with great telescopic power might be resolved into stars. The spectroscope showed, however, that they were generally composed of glowing gases, and neither the best telescopes nor the photographic plate gave indications of their resolvability, although a few stars were found to be, as it were, entangled in them.

Dr. Wallace enters with some detail into the question of the distances of the Sun and stars. I do not however propose to follow all the details, but for the most part to give merely the results without explaining minutely the methods of investigation. There are two or three ways of ascertaining the Sun's distance, and the result that has been arrived at is that the figure of 92,780,000 miles represents it with a fair amount of accuracy. It is not possible to find it with rigid exactitude, and an error of 200 or 300 thousands of miles must be allowed for—not a very formidable margin of inaccuracy after all in computing such a vast distance.

And yet this distance is nothing as compared to those of the stars. When we speak of parallax in the astronomical sense of the word, and as applied to the Sun, Moon and planets, we mean the angle made by two imaginary lines, one drawn from the heavenly body in question to the place of the observer (generally supposed to be at the equator), and the other from the same body to the centre of the Earth. The distance of the Moon is calculated with great accuracy by using the radius of the earth in this way as a base line. But when we come to the stars the case is widely different. The radius of the earth is, if it were viewed from the nearest star, simply a vanishing point. The only way of measuring these enormous distances is to take the diameter of the Earth's orbit as the base line, and to observe carefully the displacement of some particular star at intervals of six months, that is, at opposite points of this diameter of more than 185,000,000 miles in length. By observing the very slight change of position, as referred to other stars, with the fine instruments now in use, it has become practicable to calculate the distances of about sixty stars with some fair approach to certainty, though with a considerable margin of error; and perhaps twenty more with less approach to accuracy. The nearest of them all is Alpha Centauri, a star of the southern hemisphere, and not visible in these countries. It is nearly twenty-five billions of miles distant (about 275,000 times as far as the Sun); and it is computed that its light takes more than four years in travelling to us. This gives us some idea of the vast space which separates us from even our nearest neighbour in the great stellar system, particularly when we remember that the velocity of light is about 186,330 miles in a second; and it has now become the custom of astronomers to reckon stellar distances by light-years. Thus we learn that the star which is supposed to be the second in proximity to us, No. 61 in the constellation Cygnus, has a light-journey of about $7\frac{1}{4}$ years. This is a star of the fifth magnitude, a circumstance which shows that the brilliancy of a star (which is what we mean by magnitude) is no real test of its distance.

I must not omit to notice that one of the most remarkable discoveries of modern astronomy is what is termed the proper motion of the stars. I have already alluded to this, and to the light that the spectroscope has thrown upon it. It was at one time imagined that these celestial bodies were motionless, and they were called *fixed stars* (a name that still clings to them); but in many cases it has been clearly ascertained that they are moving; and though as regards the greater number of them no such movement can be detected, we suppose that this arises from their enormous distance from us, and that probably all are really in motion. If it be so, it is surely one of the most striking facts that modern science has revealed to us—nothing in the universe at rest, everything moving. How different from what was at one time supposed, even by able and enlightened men!

This leads us to the consideration of the motion of the Sun itself, which is believed by modern astronomers to exist. This was originally suggested by the apparent motions of some of the nearer stars, supposed to be really due to that of the sun, with all the planets that attend him. I do not think that this is absolutely certain, for it is just possible that these stars are truly in motion; yet as the Sun is undoubtedly a star, it is most probable that, like the others, he has a proper motion of his own. There is a doubt too as to the direction in which the Sun is moving, though probably it is towards the constellation Lyra. The rate of motion is perhaps about 12½ miles in a second; but this is to a great extent dependent upon conjecture. This solar movement is a point to be carefully borne in mind, for it has been used by one of Dr. Wallace's critics to attack an important part of his argument, as we shall hereafter see.

I may observe that in all probability as many of the stars surpass our Sun in brilliancy (as to which there can be no possible doubt), so there is every reason to believe that there are several which exceed him in size and in mass. The stars of the white or Sirian type are supposed generally to have a greater surface brilliancy than the Sun. The great star Canopus in the Southern hemisphere might be estimated (though this is rather guess work) to have a diameter more than twenty times that of our Sun. Where there are binary stars, their mass—the mass of the binary system—can be calculated with some approach to accuracy, and there is no doubt that in some cases they greatly exceed the Sun in this respect.

Our author, considering it to be necessary that in investigating the nature of the stars we should have some knowledge of our own Sun, communicates to his readers at some length what astronomers have ascertained on this subject. The sun's density is less than $1\frac{1}{2}$ times that of water, about one-fourth that of the Earth. "All the evidence goes to show that the body of the Sun is really gaseous, but so compressed by its gravitative force as to behave more like a liquid." Its diameter is about 867,000 miles. What we see as the Sun's surface is the photosphere, as it is called; and it is in fact the outer layer of this gaseous or partially liquid matter kept at a definite level by the force of gravitation. This surface is sometimes broken by what are termed sun-spots, as to the nature of which there has been considerable difference of opinion; and into this question I do not now propose to enter. Immediately above this luminous photosphere, from which are given out the light and heat which reach the Earth, there lies what is called the "reversing layer," a few hundred miles thick, somewhat cooler than the photosphere, and consisting of dense metallic vapours. "Above the reversing layer comes the chromosphere, a vast mass of rosy or scarlet emanations, surrounding the Sun to a depth of about 4,000 miles." From this issue the prominences, as they are called, from which shoot out flames with very great velocities, then again rapidly subsiding.

"Beyond the red chromosphere and prominences is the marvellous white glory of the corona, which extends to an enormous distance round the Sun." These solar envelopes, none of which have the nature of a true atmosphere, are only visible to us when the light of the photosphere is completely shut off, as is the case during a total eclipse of the Sun. They probably consist, partly at least, of liquid or vaporous matter in a very finely divided state. It is to be noted that the whole of our sunlight passes through the reversing layer and the red chromosphere, and therefore its colour is probably modified by them; so that there is reason to believe that if they were absent the light and heat of the Sun would be greater and its colour would be a purer white tending towards blue, rather than to the yellow tinge it now possesses.

I ought now to remind my readers, at least such of them as are not well acquainted with astronomy, that the greater part, if not the whole, of what I have so far put before them, being mainly the substance of the first five or six chapters of Dr. Wallace's work, consists of truths which are not now controverted by men of science. Much, on the other hand, of what follows carries us over debateable ground; though even here we shall find many things which are not only undoubted facts, but, coming from the pen of so experienced a naturalist, highly instructive and interesting.

There is one point on which he lays some stress, and here he will have the assent, I think, of the great majority of astronomers, and that is the unity of the Stellar Universe, so far as we see it or know it. This appears from what we have already learnt as to the structure and composition of the stars, which, differing though they do from one another in detail, and in some cases very considerably, yet have been shown by the spectroscope to be composed of the same elements and material compounds which we know to exist in the Earth and the Sun, though variously combined in different classes of stars. The same physical laws, moreover, appear to extend over the whole Universe. The fundamental law of gravitation is evidently in force, as is rendered almost or quite certain by the fact that double stars move around their common centre of gravity in elliptical orbits, which is precisely what they would do if under the influence of this great law. There seems also to be an identity in the laws of light, as is inferred from spectroscopic observations. Dr. Wallace, I should observe, lays some stress on the position of most of the nebulæ, lying as they do round the poles of the Milky Way, while the stars are scattered in profusion in its plane.

I think all astronomers whose opinion is worth noticing will grant the author this point—the unity of the visible universe. Nor would they dispute the general theory of the evolution of the heavenly bodies—that the stars are probably developed from nebulæ, and that they go through several stages of existence, rising to a degree of extreme heat, and subsequently cooling, till eventually they become dark cold bodies. These processes are spread over millions of years, and consequently are generally imperceptible to human observation. Our Sun is supposed to be a cooling star, but cooling so gradually that no appreciable diminution of his heat has taken place within historical times.

This, however, leads me to touch upon a subject on which there is, unquestionably, a difference of opinion. Dr. Wallace is a decided antagonist of the celebrated "nebular hypothesis"; he goes so far, indeed, as to say that during the last thirty years so many objections to it have been suggested that it has been felt impossible to retain it even as a working hypothesis. But here he is at issue with such an able astronomer as Sir Robert Ball, whose work, published in 1901, and entitled *The Earth's Beginning*, maintains the nebular theory as confidently as Dr. Wallace denies it. As many of my readers know, "this theory, very briefly stated, is that the whole of the Solar system once formed a globular or spheroidal mass of intensely heated gases, extending beyond the orbit of the outermost planet, and having a slow motion of revolution about an axis. As it cooled and contracted, its rate of revolution increased, and this became so great that at successive epochs it threw off rings, which, owing to slight irregularities, broke up, and gravitating together, formed the planets. The contraction continuing, the Sun, as we now see it, was the result."

This theory, originally suggested by the great French astronomer Laplace, has with some modifications been extensively held. There are, however, some grave objections to it. Dr. Wallace favours, on the other hand, what he terms the meteoric hypothesis. This by no means denies the existence of the primitive nebulæ, but supposes that, in the intense cold of space, the gases of the metallic and other elements would rapidly become liquid and then solid, forming meteoric dust. This matter, it is further supposed, was dispersed somewhat irregularly, and from some cause or other was all in motion. "Wherever the matter was most aggregated, there would be a centre of attraction through gravitation, which would necessarily lead to further aggregation, and the continual impacts of such aggregating matter would produce heat. The Sun would thus in course of time be formed, and would acquire sufficient heat by collision and gravitation to convert its whole body into the liquid or gaseous condition." So also subordinate centres of aggregation would form, would capture a certain proportion of the matter flowing towards the central mass, and, in consequence of the velocity with which the whole system was revolving, would circulate around the central mass, in somewhat different planes, but in the same direction. Thus the planets would be formed, Jupiter probably first, then Saturn and the other outer planets; while owing to the greater attractive power of the Sun, which would capture more of the meteoric matter flowing towards him, the inner aggregations would be smaller.

The nebulæ, of which such a number are known to exist, are, we suppose, vast aggregations of meteorites or cosmic dust, or of the more persistent gases, and possibly even now stars may be forming from them.

I do not propose to discuss the merits of the nebular hypothesis as suggested by Laplace, or of the more modern meteoritic theory. I may, however, say in passing that I do not think either of them accounts fully for the rotatory motion which pervades the whole system, and must have been in force from the earliest beginnings.

I have already mentioned a very interesting discovery which has been made in modern times—the existence of great numbers of double and multiple stars. During the century that has recently come to its close, many thousands of double stars have been discovered by the telescope; and these are by no means all, for still more recently the spectroscope has revealed the fact that there is a vast number of double stars that the telescope could not discover, which are really double, though appearing as single stars even in the most powerful telescopes. These are termed *spectroscopic binaries*.

The times of revolution of these double stars around their common centre of gravity varies from a considerable number of years down to months and days, so that in some cases they must be in close proximity. Indeed, it is supposed that there are instances in which, owing to very rapid rotation, stars have undergone disruption and have divided themselves into two, thus becoming double stars revolving at a small distance around their centre of gravity.

There are more than twenty stars which have each of them what is called a dark companion, that is, a large non-luminous body, which being very close to the star obscures it either wholly or partially during each revolution, the two, of course (as in the case of bright stars), revolving around the common centre of gravity. Some of these are believed to be as large as our Sun, or even larger; five of them are said to be revolving in absolute contact, forming systems of the shape of a dumb-bell.

I beg my readers to pay special attention to all these things: if it be true that, as Professor Campbell (of the Lick Observatory, in America) has suggested, that most stars will prove to be, generally speaking, double or *spectroscopic binaries*; or even if this estimate be somewhat exaggerated, yet it is evident that in a very great number of stellar systems a totally different state of things prevails from that with which we are familiar in our own solar system, and consequently the chances of there being bodies where organic life exists as it does on our Earth are incalculably diminished.

I must not pass over the remarkable phenomena of *clusters* of stars, "which are literally abundant in the heavens," in some of which more than 6,000 stars have been counted, besides considerable numbers so crowded in the centre as to be difficult or impossible to count. It is surmised that in these clusters we have the result of the condensation of "large nebulæ, which have first aggregated towards numerous centres while these agglomerations have been slowly drawn towards the common centre of gravity of the whole mass." There are some large nebulæ near the borders of the Milky Way, and it is in, or near to, the Milky Way that star-clusters are excessively abundant. It should be remarked that there are in the globular clusters a large quantity of variable stars; and "when we consider," as our author puts it, "that variable stars form only a portion, and necessarily a very small proportion, of binary systems of stars, it follows that in all the clusters which show a large proportion of variables, a very much larger proportion—in some cases perhaps all—must be double and multiple stars revolving round each other." This appears to be the opinion of Professor Newcomb, who is quoted as having said that "it is probable, among the stars in general, single stars are the exception rather than the rule."

Dr. Wallace discusses at some length the question whether the stars are infinite in number. It is of some importance to his argument, because, as we shall presently see, he relies on our (real or supposed) central position in the visible universe as pointing to the conclusion he desires to draw—that the Earth is the one great abode of the higher forms of life. If the universe were infinite in extent, it is obvious that this argument would be seriously weakened; for who can say what is the central position in a universe that stretches out to infinity, or whether there is any centre at all? Dr. Wallace endeavours to show that even if it were so, and there were an infinite number of stars distributed through endless space, and if there were systems totally distinct from our own in structure and so remote that they have no influence on us yet our position within the stellar universe (that we know) might have the same importance as it has under the assumption that the universe is finite. At the same time I think it must be allowed that the supposition of an infinite universe, strictly and really such, would materially damage his argument. He takes, however, the better and stronger ground of denying the probability of such an infinity existing and gives his reasons accordingly. One reason is that if there were an infinite number of stars scattered through infinite space there would be such a blaze of light in the sky as would be theoretically greater than sunlight. He quotes the great American astronomer Professor Newcomb, who has made a mathematical calculation to that effect; but his calculation depends on the condition that "every great portion of space is, in the general average, equally rich in stars," and it is obvious that you cannot be sure of any such condition. Besides which, however strong the theoretical argument may be, we have this practical fact before us: that a number of stars, owing either to their comparatively small size, or more probably to their enormously remote distance, are absolutely invisible even in the most powerful telescopes and are only known to us through the medium of photographic plates; and I confess that I do not see how stars that are still more remote—so distant, indeed, that they cannot even be photographed—could go very far towards producing such a blaze of light as supposed. Another objection to this argument has been raised, namely, that there are probably, if not certainly, a number of dark bodies in the universe as well as the bright stars, and these bodies might obscure the light of their bright companions. But it may be replied that the dark bodies do not obscure the millions of stars that we now see so as to prevent their light from reaching us; and we may well ask why they should do so in the supposed infinite distance beyond. I do not, therefore, attach very much weight to this objection; nor, as I have already said, very much weight to the argument it is intended to meet.

A stronger reason, however, is that in the case of those stars which are visible in very powerful instruments there appears to be a very rapid diminution in the number of the fainter as compared with the brighter ones, a circumstance which tends to indicate that their number is finite. Moreover, there are all over the heavens areas of some considerable extent where stars are either quite absent, or very faint, and few in number; so that when we look at them we probably "see completely through our stellar universe into the starless depths of space beyond."

There is, of course, a difference of opinion amongst astronomers on this question. Speaking for myself, I do not believe that there is anything infinite in the whole world, God alone excepted. There are, no doubt, persons who hold that space in infinite. But what is space? A question more easily asked than answered.* Let us then grant to Dr. Wallace that the stellar universe is not infinite, and proceed to consider his argument as to the position of the solar system (of which we form a part) with regard to the Milky Way, and to the whole stellar universe. The Milky Way, he tells us, and I think tells us truly, notwithstanding its irregularities and divisions, forms a great circle in the heavens. He also quotes Professor Newcomb, Miss Agnes Clerke, and others, as holding that we are situated in the plane of this great circle. Again, after quoting Sir Norman Lockyer's opinion that the solar system is in the centre, he goes on to say that the conclusions of some of the most eminent astronomers point to the inference that our position is *not very far from the centre* of the vast ring of stars constituting the Milky Way. It appears that Dr. Wallace, in one of his magazine articles, rather overstated this conclusion, and put it as if we were exactly in the centre of the universe; and for this he was severely criticised by Professor Turner (in the *Fortnightly Review* for April, 1903). It is rather strange that the criticism should have come from that quarter, for, if my memory does not deceive me, I heard Professor Turner himself, at a meeting of the Royal Astronomical Society, of which he is, during this year, the president, make this very remark—that we are apparently in the centre of the universe (I suppose he meant *approximately* so). This occurred a few months ago, presumably since the date of his critical article. Whether he has reconsidered his first opinion or whether he intended to direct his criticism merely against Dr. Wallace's over-statement, I do not know.

Mr. Maunder, in a fair and generous review of the

* It is true that in advanced mathematics we have to deal with infinities, quantities infinitely great and infinitely small; but, as students of the science know, these are not absolute but relative infinities; just as (to take an illustration from astronomy) the radius of the earth, great as it is, and furnishing a base line sufficient for calculating the distance of the moon and some other heavenly bodies, is simply a vanishing point as it would appear from the nearest star, the distance of which is *relatively* infinite as compared to it.

present work in the scientific publication called *Knowledge* (December, 1903), draws a distinction between the two, and quite admits the truth of a modified statement, that "in this very loose sense [*i.e.*, as stated in the present volume] the Sun is central in the central plane of the Milky Way." The fact of our central position, if it be true, is obviously a very striking one and highly suggestive. But Professor Turner has another objection to make—and he is not the only one who makes it—arising from the probable motion of the solar system in space, owing to which, even if the Sun is now in the centre of the visible universe, he was not so in times past and will not be so in the future. Dr. Wallace has two answers to give to this objection—one is, that it is not quite certain that the solar system is moving in this way: it has been inferred from some apparent motions of the stars, which are most readily explained in this way; but there may be another explanation, and he quotes Miss Agnes Clerke and Mr. Monck as suggesting the possibility of the motions of these stars being not merely apparent but real, so that these observed facts might be reconciled with the supposition of a motionless sun. Another and a stronger answer is that the critics have argued as if the Sun were moving in a straight line, which is extremely improbable, if not impossible. If the Sun is in motion, it is doubtless under the influence of the law of gravitation, and therefore in all probability in an elliptic orbit, which would, in fact, bring him in the long course of years to the same point (approximately) which he previously occupied.

I think, then, that it must be conceded to Dr. Wallace that, in the modified sense mentioned above, he has shown that the solar system is situated *near*, or comparatively near, to the centre of the stellar universe. Such a fact, important though it be, may not go very far in the way of proof; if, however, as may well be said in this case, there is no question of positive proof, but only of balancing probabilities, then the nearly central position of our system must be allowed to have some weight.

Our author considers it also to be a fairly well-established fact that we are surrounded by a cluster of stars of unknown extent, not far removed from the centre of the galactic plane, and that these stars are generally of the solar type ; but I do not see how this strengthens his case, particularly as he does not seem quite clear as to the position of the Sun in this cluster, in one place putting it "not far from the centre of this group," and in another passage placing it "towards the outer margin of the dense central portion of the solar cluster," and revolving, with other stars, around the centre of gravity of the cluster.

Here for the present I must pause, and I propose in the next number of this Review to explain Dr. Wallace's striking argument in favour of his opinion, drawn from the nicely balanced condition of various circumstances which render this Earth a fit habitation for man and for the more highly organised animals.

F. R. WEGG-PROSSER.

(To be continued.)

Art. VII.—"MAN'S PLACE IN THE UNIVERSE."

Part II.

BEFORE proceeding with the explanation of Dr. Wallace's argument, by which he maintains his opinion that this Earth is *probably* the one only abode in the Universe of highly organized, or at least intelligent, life, I wish to recall to the minds of my readers a few of the leading conclusions at which we have already arrived. One of these is the remarkable fact that our Sun and the accompanying planets are situated *approximately* in the centre of the Stellar Universe, so far as we know it; a circumstance which does not absolutely prove anything, but suggests to the mind something peculiar and exceptional about the Solar System; which also the enormous distance of the Sun from the nearest star seems to corroborate. This presumes (and I think we may say rightly) that the physical Universe is not infinite in extent.

Then another noteworthy circumstance is that a large number of the stars are undoubtedly what we term double stars; indeed, in some cases, triple or multiple systems, two or more stars revolving around their common centre of gravity: here again, though there is nothing conclusive, we have a state of things so widely different from what exists in our own system, that we may infer, and not unreasonably, that there are no planets circulating around these stars resembling our own Earth in its suitability for the production and maintenance of life. The case of the planets of the Solar System is considered later on, and we shall see what our author has to say on that part of the subject.

We are now approaching the most interesting part of Dr. Wallace's work, in which he treats of what he terms "the delicate balance of conditions which alone renders organic life possible on any planet"; and here he is treading on fairly safe and sure ground; he adds that these conditions must not only "be such as to render life possible *now*," but that they "must have persisted during the long geological epochs needed for the slow development of life from its most rudimentary forms," as to which, perhaps, we cannot be quite so certain, especially when we are considering the case of other planets than our own.

First of all, however, he calls our attention to the "uniformity of matter," and the identity of "the elements and material compounds in Earth and Sun, stars and nebulæ." A large number of the elements known to us here have been found to exist in the Sun. Some of the stars appear to have nearly the same chemical constitution, while others differ in detail and exhibit mainly lines of hydrogen. Of the nebulæ, comparatively little is known.

It is to the spectroscope that we are indebted for all this knowledge, and a remarkable corroboration is afforded by the analysis of the meteorites which not infrequently fall on the Earth: they may be supposed to give us samples of planetary matter; and if it be true that many of them have been produced by the débris of comets, it is probable that they bring us matter from the remoter regions of space. None of these meteorites have been found to contain a non-terrestrial element, and as many as twenty-four known elements have been discovered in them.

Moreover, we have, besides the general identity of the elements of matter, a uniformity in some of the most important laws that govern it. Thus it seems evident that the law of gravitation extends to the whole physical universe, this being well illustrated by the motion of double stars around their common centre of gravity in elliptical orbits. The laws of light also are evidently the same throughout the solar system as those upon Earth; and, as we gather from spectroscopic observation, the same also in the far distant regions of the stars; and, indeed, as our author tells us, "we have in some cases been actually enabled to reproduce in our laboratories phenomena with which we had first become acquainted in the Sun or among the stars." From all this he infers, and surely not without reason, that living beings, wherever in this universe they may exist, must be in essential nature the same everywhere. I cannot refrain from quoting the following passage, so well worthy of the reader's attention, *in extenso:* "The outward forms of life, if they exist elsewhere, may vary almost infinitely, as they do vary on the earth; but throughout all this variety of form—from fungus or moss to rose-bush, palm, or oak; from mollusc, worm, or butterfly to humming-bird, elephant, or man—the biologist recognises a fundamental unity of substance and of structure dependent on the absolute requirements of the growing, moving, developing, living organism built up of the same elements, combined in the same proportions, and subject to the same laws."

The author does not deny that organic life might exist under wholly different conditions in other universes, where other substances replace the matter of our own universe, and other laws prevail. But *within* the universe we know, there is no reason to suppose such a thing to be possible, excepting under the conditions and laws which prevail here. This contention surely is reasonable; moreover, the question which is really interesting is whether it is probable that there are, as inhabitants of other worlds, intelligent and responsible creatures such as man, not whether there are monsters or low types of animal life; though even as to these Dr. Wallace would scarcely admit them. And it may be noted that the enthusiasts who have been anxious to people the planets with inhabitants, suppose them to be gifted with human intelligence—as witness the absurdities in which some of them indulged during the opposition of the planet Mars, and his comparative approach to the Earth, a few years ago.

The portion of the volume before us, which I am now considering, has an especial interest, because here the veteran biologist is at his best. When he treats of "essential life-conditions," and "the Earth in relation to life," and kindred subjects, he is dealing with scientific matter on which he is eminently qualified to speak, and of which he probably knows as much as any man living. I wish indeed I could persuade such of my readers as have access to the work to read carefully and in detail all those chapters in which these subjects are so skilfully handled, and of which I can scarcely hope to be able to convey an adequate idea in the sketch which my limited space permits me to make.

The author observes that before trying to comprehend the conditions necessary for the development and maintenance of organic life comparable to what we have on this Earth, we must obtain some knowledge of what life is. Now the living body, at least in its higher developments, consists of complex but unstable forms of matter, all of which is in a continual state of growth or decay. It absorbs matter from without, acts upon it mechanically and chemically, rejecting what is useless, and transforming the remainder so as to renew its own structure, and throwing off, particle by particle, the worn-out portions of its own substance. Then, in order to do this, its whole body is permeated throughout by branching vessels or porous tissues, by which liquids and gases can reach every part and carry on the above-named processes. Besides all this, living organisms have the power of reproduction: in the lowest forms by a process of self-division or "fission"; in the higher by means of reproductive cells, which possess the mysterious power of developing a perfect organism identical with its parents even in minute details, reproduced as they are with close accuracy, though often involving metamorphic changes during growth of so strange a nature that if they were not familiar to us they would be treated as incredible. Our author refers again to this a little later on, and he evidently considers it one of the most curious, not to say puzzling, of all the phenomena of life. He says, "Every living thing of the higher orders arises from a microscopic single cell when fertilized, as it is termed, by the absorption of another microscopic cell derived from a different individual. These cells are often, even under the highest powers of the microscope, hardly distinguishable from the cells which occur in all animals and plants, and of which their structure is built up; yet these special cells begin to grow in a totally different manner, and instead of forming one particular part of the organism, develop inevitably into a complete living thing with all the organs, powers, and peculiarities of its parents, so as to be recognizably of the same species." He evidently thinks this a "mystery" not easily solved; all the more when we consider the growth of thousands of complex organisms with various peculiarities, and all arising from these minute cells or germs, the diverse natures of which are indistinguishable even by powerful microscopes, but which differ so widely in their development.

The physical basis of life is protoplasm, consisting essentially of four common elements, the three gases, nitrogen, hydrogen, and oxygen, with carbon; and, with regard to this last, the chemical compounds of carbon are more numerous than those of all the other chemical elements combined; and this explains the fact that the animal tissues, such as skin, hair, nails, muscle, etc., consist of the same four elements (with occasionally minute quantities of sulphur and other substances), so that these tissues are produced as well in the grass-eating sheep or ox as in the carnivorous tiger. Innumerable diverse substances are formed out of the same three or four elements, the endless variety of organic acids, fruits, sugars, gums, oil, camphor, resins, medicinal alkaloids, the essential principles of tea, coffee, and cocoa, with very many other things. "If this were not indisputably proved it would scarcely be credited."

It seems that the most important element in protoplasm is nitrogen, which readily enters into compounds; ammonia (a compound of nitrogen and hydrogen, produced by electric discharges through the atmosphere) being an instance. Plants by their leaves absorb oxygen and carbon-dioxide; and by their roots absorb water, in which ammonia and oxides of nitrogen are dissolved, and thus they produce protoplasm. But, as stated by Professor F. J. Allen, all this sensitiveness of nitrogen, and its proneness to change its state of combination and energy, appear to depend on certain conditions of temperature and pressure, which exist at the surface of this Earth.

An important fact is the existence in the atmosphere of a small proportion of carbonic acid gas. The leaves of plants absorb this gas by the means of a peculiar substance, chlorophyll, from which they derive their green colour, and which has the power, under the influence of sun-light, to decompose it, the carbon being used to build up the structure of the plant, while the oxygen is given out; so that the leaves of plants are not merely ornamental appendages, but most marvellous structures, doing what no other agency in nature can perform.

Besides absorbing carbonic acid, plants as well as animals continually absorb oxygen from the atmosphere. Thus is built up the wonderful beauty of the vegetable world, with bud and foliage, flower and fruit, more indispensable to our nature than the world of animals; for, as our author remarks, "we *could* have plants without animals; we could *not* have animals without plants."

It must be observed that protoplasm, being a structure of atoms built up into a molecule, is only the starting point or material out of which the varied living bodies are formed. Thus proteids are formed when sulphur in small quantities is absorbed into the molecular structure, chiefly in the case of animals; so also a number of other elements, such as phosphorus, sodium, potassium, are absorbed and moulded, everything being utilized and finding its proper place.

Dr. Wallace, in continuation of his argument, proceeds to discuss certain physical conditions essential for the support of organic life on the surface of our Earth. First, there is the regularity of heat supply, with a limited range of temperature. Vital phenomena, he tells us, for the most part occur between the temperatures of freezing water and 104° Fahr.—this being supposed to be due mainly to the properties of nitrogen and its compounds. A small increase or decrease of temperature beyond these limits, if continued for any considerable time, would destroy most existing forms of life. It is worth noting that the normal blood heat in a man, which is 98° Fahr., is constantly maintained within one or two degrees, notwithstanding the great range of external temperature. With the exception of man and a few of the higher animals, which are so perfectly organized as to be able to adapt themselves to some comparatively extreme conditions of heat and cold, the great majority cannot do so.*

The second essential condition is a sufficient amount of solar light and heat. It is doubtful whether the higher animals and man could have been developed without solar light; and it is clear that without plant-life land animals could not have existed. The plant alone can take out of the small proportion of carbonic acid in the air that carbon which is so necessary for building up its structure. It does this by the agency of solar light, and even of a special portion of that light. The question is therefore raised whether *any* sun would answer the purpose: our Sun does so, but the stars differ greatly in their spectra, and therefore in the nature of their light; and it is quite possible that they would not all be able so to act.

The third condition is abundance of water, the necessity of which is so obvious that it need scarcely be discussed; it constitutes, in fact, a very large proportion of the material of every living organism, and about three-fourths of our own bodies. Later on attention is called to the special conditions that have secured the continuous distribution of water on the Earth.

A fourth condition for development of life is an atmosphere of sufficient density and composed of suitable gases; the coincidence of which, it is remarked, may be a rare phenomenon in the universe. A rather dense atmosphere is an important necessity as a regulator of temperature and a reservoir of heat. At about 18,000 feet above the level of the sea the atmosphere is half its density at the sea level. We know what a temperature exists at such an altitude; and if it existed at the surface of the earth, life in its higher forms would be hardly possible; and there would be a deficiency in the needful supply of oxygen to animals and

* It is, however, to be remarked that the anthropoid apes, natives chiefly if not entirely of tropical countries, cannot without the greatest difficulty be made to live in a cold, damp climate like England; whilst some coarser animals, if we may so term them, such as lions and bears, seem to adapt themselves to almost any climate.

carbonic acid to plants. Indeed, the combination of gases in the atmosphere—oxygen, nitrogen, and the small proportions of carbonic acid and ammonia—is apparently indispensably requisite for plants, and consequently for animals. The aqueous vapour also, which exists in the air, is essential to plants, supplying hydrogen, and preventing too rapid a loss of moisture from the leaves.

The last important condition is the alternation of day and night. The author admits that it is possible that in a world of perpetual day or night life *might* have been developed; still, considering the varied circumstances which combine to its preservation and renewal, anything of even a slight character might turn the scale against it. Thus the average duration of day and night, about twelve hours for each, in the tropics, prevents the earth from becoming heated to such a point as to be inimical to life. Supposing the day and night were very much longer, say fifty or one hundred hours each, the great and continual contrasts of heat and cold would probably have been most injurious.

So again the distance that the Earth is from the Sun tends towards a comparatively moderate temperature, while the equalizing power of air and water, distributed as they are with us, acts in the same way, preserving a great portion of the earth from the extremes of heat and cold. If we were at half the distance from the Sun which we now are, we should have four times the heat; and on the other hand, if at twice the distance we should have only one-fourth of the heat we have now.

So also the obliquity of the ecliptic, causing the change of seasons and the inequality of day and night in the temperate zones, is a more important matter than some people imagine. If, for instance, the Earth's axis were as that of Uranus is believed to be, almost exactly in the plane of its orbit, the contrasts of heat and cold would be simply overpowering. On the other hand, if the axis were at right angles to the plane of the orbit, though such a state of things would be much more favourable, there would probably be grave counterbalancing disadvantages, preventing some considerable part of the Earth's surface from supporting the varied vegetable and animal life that it now does.

It is a curious fact, well known to geologists, that in remote ages the climate of the earth was more uniform than it is now. Dr. Wallace considers that this can be best explained by a slightly different distribution of sea and land, which allowed the warm waters of the tropical oceans to penetrate into various parts of the continents (more broken up than they are now), and also to extend into the Arctic regions. At any rate, there is no doubt of the fact, as the remains of fossil plants and trees found on the west coast of Greenland in 70° N. lat., and even to some extent in Spitzbergen in lat. 78° and 79°, prove incontestably. Some of the great coal beds of the world were formed from a luxuriant vegetation such as does not now exist in the same latitudes. This is supposed to indicate an atmosphere in which carbonic acid gas was much more abundant than it is now; and the probability of this is increased by there being at that period a small number and low type of terrestrial animals. There seems to have been a denser and more vapour-laden atmosphere, acting as a sort of blanket over the earth and preserving the heat brought by the ocean currents from the tropics to the Arctic seas.

There were, however, great changes of climate and indications of ice action, the cause of which is not so evident. On the whole there was a continuity of conditions favourable to life, and particularly to an abundant vegetation.

Many persons are aware that the oceans occupy more than two-thirds of the whole surface of the globe; but it is not so generally known that the mean depth of the water is more than six times the mean height of the land. This is due to the enormous depths of the oceans over very large areas, while most of the land area is occupied by lowlands, mountains and high plateaus, forming a comparatively small portion of it, so that it has been calculated that if all the land-surface and ocean floors could be reduced to one level, the whole would be covered with water about two miles deep.

Our author holds, contrary to the opinion of some geologists and biologists, that the continents and oceans have not changed places since the ancient geological times, but that the features of the surface of the globe are on the whole and in the main what they then were. He gives good reasons for this opinion, remarking also that had the great oceanic basins been unstable, changing places at various periods with the land, they would almost certainly have swallowed up the land in their vast abysses.

As to the way in which the ocean depths were produced, he inclines to the opinion of Professor George Darwin (a very great mathematical astronomer); with regard to the origin of the Moon, to an opinion published in a popular form by Sir Robert Ball. This supposes the bulk of the Moon to have been detached from the Earth at that remote period when the crust of the latter was in a much less stable condition, and its rotation much more rapid; then there was left, of course, a vast chasm in the earth, which became filled with water, and thus was formed the Pacific ocean; while owing to tidal action on the opposite side of the earth, the Atlantic ocean was also formed. Those who are interested in these matters will do well to peruse Chapter xii. of the work before us. However this may have been, there is no question of the importance of this vast bulk of water in regulating the temperature of the globe. Owing to the property of water in absorbing heat, the surface of the tropical oceans becomes warm to a depth of several feet; this warms the lower and denser portions of the air, and this warmth is carried to various parts of the earth by the winds; while the great ocean currents, such as the Gulf stream, carry the warm water of the tropics to temperate or even arctic regions. Besides all which, the great ocean area forms a vast evaporating surface, from which the land derives most of its water in the form of rain and thereby of rivers.

What has determined the total quantity of water on our globe is not known; but presumably it may have depended on the mass of the earth being sufficient to retain by its gravitative force the oxygen and hydrogen of which water is composed. The important point is that, were it not for the deep ocean basins, supposing the same quantity of water to exist, it would overflow the land to a considerable depth, leaving the tops only of high mountains and plateaus above the surface of the water.

If then the quantity of water on the earth is so important for our well-being, what must we not think as to the value of the atmosphere, such as it exists? Besides its supplying us with oxygen through respiration, the winds that it produces bring about an equilization of temperature, and also distribute moisture over the earth by means of clouds. The hurricanes that occur in some latitudes are formidable as it is; but if the air were denser than is the case, their force would be far more destructive; and if there were a much greater amount of sun heat, these tempests might become so frequent as to render considerable portions of the world uninhabitable. Then again the trade-winds have an important function in initiating the ocean currents which have so great an effect in equalizing temperature, the Gulf stream being a well-known instance.

So also wherever the winds blow over extensive areas of water on to the land, clouds are formed, and more or less rain falls; and thus the larger portion of the surface of the earth is well supplied with rain, which, falling most abundantly in the elevated and cooler regions, percolates the soil and gives rise to springs and rivulets; and these uniting together form rivers, which again return to the sea the water from which they were derived.

Much of this has long been well known; but there is another fact not so generally understood, still proved by experiment, and that is the abundance of minute dust particles in the air. The density of a cloud depends on these as well as on the quantity of vapour. These dust particles serve more than one purpose: in the higher atmosphere they become very cold, and condense the vapour, thus assisting materially in the production of rain. Then the blue colour of the sky is believed to be due to them, since they reflect the light of short wavelengths from the blue end of the spectrum; in the lower atmosphere, however, the particles are larger, and reflect all the rays, thus diluting the blue colour near the horizon, as the various hues of sunset show to us. This power of reflecting light that the particles of dust possess is of immense consequence to us in another way, as our author tells us: were it not for them the sky would appear black even at noon, except in the actual direction of the Sun, and we should not receive the light from the sky we now do. It is difficult to say what effect this kind of light would have on vegetation ; but owing to the constant sunshine during the day, the soil would tend to become arid and bare in places that are now covered with plants of various kinds.

This dust, it appears, comes from volcanoes and deserts and arid regions of the world, and is carried by the density and mobility of the atmosphere to a great height, and distributed by the motion of the air in all directions. If the atmosphere were half as dense as it now is, the winds would have less carrying power, and possibly fogs close to the surface of the ground would take the place of the clouds that now float above it. There would be a diminished rainfall, and other injurious consequences. This density again depends on two factors—the force of gravity due to the mass of the planet and the absolute quantity of free gases constituting the atmosphere.

There is one more fact to be noticed. Vegetable organisms obtain the chief part of the nitrogen they require from ammonia, carried into the earth by rain. Now this substance is produced by the agency of electrical discharges causing the combination of the hydrogen in the aqueous vapour with the nitrogen of the air. Here again clouds are most important agents in accumulating electricity in sufficient amounts to cause the violent discharges which we call lightning, and which, destructive as we know them sometimes to be, appear to be beneficial in a way that few people suspect.

Our author, in order to show how nicely adjusted are all our conditions on this earth, points out that if the mass of the globe were much smaller than it is, the lighter atmospheric gases would not be held on its surface. So again if the mass had been much greater, say double what it is now, the quantity of gases attracted and retained by gravity would probably have been double, and so a much greater quantity of water would have been produced, since no hydrogen could then escape, and the water would perhaps have sufficed to cover the surface of the earth several miles deep.

We now arrive at the momentous question as to the inferences to be drawn from all the facts that have been here stated, many of which facts are undoubtedly such as would be admitted by all men of science.

I may remark, before going further, that one of Dr. Wallace's critics expressed a suspicion that he had been influenced by some religious bias in the conclusion which he had drawn. I do not, of course, know how far that may or may not be true; but though he touches once or twice on the religious question, once at the beginning of his work when referring to the opinion of Sir David Brewster and others, and again in a remarkable passage at the close of the volume, he certainly argues the question on purely scientific grounds, and upon these he must be answered if answered at all.

To return however to our author's arguments—beginning with the solar system—he recalls to our minds how numerous and how delicate are the conditions here on earth which are requisite for the preservation of a sufficiently uniform temperature. Is it then likely that any of the other planets, which have either much more or much less sun heat than we receive, could by any possible modification of conditions be rendered capable of supporting a full and varied life development?

I may at once observe that as regards the outer planets, the larger orbs of our system, he simply rules them out of court. Their remoteness from the sun and the comparatively small quantity of light and heat that they receive from him, is of course a formidable drawback to the development of organic life. But that is not all: their low density is almost conclusive against them as abodes of life; Jupiter is less than one-fourth the density of the earth, and the others still less. They are supposed to retain a considerabe amount of internal heat, and to be almost gaseous in their structure. It is not at all likely that they are inhabited; and I believe that Dr. Wallace would on this point have the concurrence of most, if not all, modern astronomers.

As to the inner group of four planets, the question is not quite so clear, and yet even here much may be said against the probabilities of their being abodes of life, that is, life such as we know it, the Earth of course excepted. Mercury is a small planet, its mass being about one-thirtieth that of the Earth, and it probably cannot retain aqueous vapour and the lighter gases, and if so it possesses very little atmosphere. Our author says that it keeps one face always to the sun (its day being equal in length to its year); and if that be the case the extremes of heat and cold in a planet so near the sun must be excessive. This, however, is by no means known for certain, for it is difficult to determine by observation. Still, I think on the whole that the case against Mercury being habitable is a strong one.

Venus, on the other hand, has in all probability a dense atmosphere, a great moderator of temperature, but the planet is ruled out by our author on the same ground partly as Mercury, that of rotating on its own axis in the same time that it revolves round the sun, under which circumstances the violent changes of temperature would be almost prohibitive of animal and perhaps vegetable life. But it is doubtful whether this is the fact, for Venus appears to be enveloped in a cloud canopy, and there are no marks on such a surface by which we can judge at all accurately of the period of axial rotation. The opinion of modern astronomers tends to agree with what Dr. Wallace states, and therefore the probability is rather against the planet being habitable than in favour of it.

There remains the planet Mars, which has afforded a sort of playground for misguided enthusiasts. Mr. Maunder, a generous critic, though he criticizes a too hasty judgment of Dr. Wallace's, seems to feel indebted to him for his opinion against the habitability of Mars, as a protest against the absurdities of some of those writers who imagine that the so-called canals in the planet are the work of skilled engineers, and even that certain white spots on the terminator are signals to the inhabitants of the Earth.*

The author of this work holds that Mars contains no water or aqueous vapour in its atmosphere, and that its apparent polar snows are caused by carbonic acid or some other heavy gas. The absence of aqueous vapour is the point on which Mr. Maunder criticizes him, considering the evidence to be insufficient. Mars is much smaller than the earth, and owing to its greater distance from the sun receives less than half the amount of heat from him per unit of surface that we do. It is most likely that its atmosphere is very rare, and apparently contains scarcely any clouds, judging from its low reflecting power. From all which circumstances we may infer that its surface temperature is, during the greater part of its day, very low. On the whole it must be considered to be doubtful if it can support anything but a low type of vegetable life; but this is all we can say—certainty is not attainable.

Dr. Wallace reminds us of the well-known difference of opinion between geologists and physicists as to the duration in years of life on the Earth. Considering the great length of the tertiary period, "during which *all* the great groups of the higher animals were developed from a comparatively few generalized ancestral forms," and the still greater length of the secondary and primary periods, geologists have concluded that two hundred millions of years are required to account for all that has taken place from the earliest forms of life (as represented by fossilized remains) to the present age. Dr. Wallace puts a million of years for the human era, but here I think there must be some mistake, for I do not remember ever to have seen so extravagant an estimate. Some geologists have assigned one hundred thousand years to the time of man's life on the earth, and the more moderate ones have said thirty thousand. To my mind it is hardly credible that one million years should have elapsed without some trace of historical record having been

* Some of these theorists, at the time when Mars was in opposition (a few years ago), seem to have been so ignorant of even the rudiments of astronomy as not to know that at that time the earth would hardly be visible at all from Mars, excepting as a small black spot crossing the sun in case of a transit.

left by primæval man. But to return to the question between geologists and physicists, he quotes Lord Kelvin as maintaining that the whole life of our Sun as a luminary is probably less than fifty millions, but possibly between fifty and one hundred million years. He holds that there are reasons for thinking that the biological and other changes may have gone on more quickly than has been supposed; and that geological time may possibly be reduced so as to meet the maximum period allowed by astronomers; but there will certainly be no time to spare; and it must also be remembered that our Sun is now cooling, and that its future life will be less than its past. If, then, these things be true, he holds that no other planet has developed or can develop such a complete life series as we have on the earth. Mercury, Venus, and Mars could not have preserved equability of conditions long enough for life development; and Jupiter, and the planets beyond him, will require a long time to become cool enough for such a purpose; while the Sun also will become cooler (and perhaps rapidly so), and they will not have the requisite heat from him. So it is most likely that they will never be abodes of life. And now, if I may be allowed to sum up, I may say that I think as regards our own system Dr. Wallace, though with some little exaggeration, has fairly made out his case; and that considering the vast period of time during which the Earth was unfit for habitation, and the relatively short period since its higher forms of life appeared, and also the delicate balance of conditions under which life even now exists, the chances (if I may venture so to express myself) are against any of the other planets being in a state at present —and I do not wish now to discuss the possible future— for developing and maintaining life, at least in its higher and more perfect form. Our globe is, therefore, I think, so far as the solar system is concerned, the one great life-house of creation.

But a far more difficult question arises when we come to deal with the stellar universe. Dr. Wallace, however, does not shrink from it. First, he remarks that while many of the brighest stars are much larger than the Sun, probably ten times as many are smaller. The whole duration of our own Sun has only been just sufficient, as it appears, for the development of life on the Earth ; and suns that are much smaller are unsuited to give adequate light and heat for a sufficient time and with sufficient uniformity for such life-development on any supposed planet attached to them, even allowing for other necessary conditions. He goes on to say : "We must probably rule out as unfitted for life-development the whole region of the Milky Way, on account of the excessive forces there in action, as shown by the immense size of many of the stars, their enormous heat-giving power, the crowding of stars and nebulous matter, the great number of star clusters, and especially because it is the region of 'new stars,' which imply collisions of masses of matter sufficiently large to become visible from the immense distance we are from them, but yet excessively small as compared with suns, the duration of whose light is to be measured by millions of years. Hence the Milky Way is the theatre of extreme activity and motion ; it is comparatively crowded with matter undergoing continual change, and is therefore not sufficiently stable for long periods to be at all likely to possess habitable worlds."

The stars most likely to have planets suitable for life-development, if indeed there are any such, are those composing the solar cluster; they are a small number compared with the "hundreds of millions" estimated by some astronomers to be in the stellar universe. And yet, even here, there are probably many that are unsuitable. Professor Newcomb holds that the stars in general have a much smaller mass in proportion to the light they give than our Sun has ; also that the brighter stars are, on the average, much less dense than the Sun, so they cannot give light and heat for so long a period ; then, even of those of the solar type and of an equal mass with the Sun, only a portion of the period of their luminosity would be suitable for the support of planetary life.

Our author raises a question as to the stability of the star system, and is inclined to the opinion that other forces besides that of gravitation—electro-dynamical, for instance

—are acting on them; and he also attaches considerable weight to our comparatively central position. As regards this last point, I follow him so far as thinking it highly suggestive of some peculiar advantage to our system; but it will not do to press it too far; and when he attributes our uniform heat supply to this central position, he is obviously treading on very uncertain ground.

The strong point in his favour, I think, is the discovery of such a number of double, and in some cases multiple, stars; the spectroscopic binaries as they are called, that is, pairs of stars, which appear like a single star in the most powerful telescopes, are known to be numerous, and may prove to be far more numerous still; and we see at once that in such systems the probability of there being life-producing planets is very small. Then if we add to these the stars still in process of aggregation, the remaining ones which may conceivably have planets revolving round them, and those planets suitable to life, may be after all not very many.

But after granting all this, it is plain that we must leave the question in a state of profound uncertainty. It is known that there are dark bodies revolving with some stars around their common centre of gravity, and it is not easy to rule out all these as being utterly unfit for supporting life. Yet, as we are only balancing probabilities, perhaps the scale weighs more heavily against the existence of these life-producing planets than for them.

There is an interesting dissertation in the work before us as to whether the stars are beneficial to us. They give, of course, a certain amount of light, however comparatively small; but it also seems very possible that the radiation from them has some chemical action on the leaves of plants. These considerations are in answer to those who think that the stars, if not centres of life-bearing planets, must be held to be useless. I do not myself think that arguments of this nature require an elaborate answer: we cannot penetrate into the counsels of an Almighty Creator, and we must be contented in many things to remain in ignorance. At the same time, if our author is right in assuring us that the light of the very faintest stars does produce distinct chemical changes, and that possibly the large amount of growth of foliage that takes place at night may be partly due to this agency, such a fact is, of course, very curious and instructive.

Dr. Wallace appears to be confident that he has proved his thesis, that is, of course, so far as it is susceptible of proof, "that man, the culmination of conscious organic life, has been developed here only in the whole vast material universe we see around us." His argument seems to go further, and to extend to all the highly organised animals; but we need not trouble ourselves much about them; and it is, perhaps, better for the present purpose to confine our attention to the human race. If this be so, he thinks there are two explanations: one which he thinks will probably be adopted by men of science, most of them perhaps—that the conclusion is true, but due to a fortunate coincidence. My own humble opinion is rather that they will deny that the evidence is sufficient, and will dispute the conclusion altogether. But however this may be, it is to be noted that Dr. Wallace believes that there is another body of men, and probably much the largest, who holding the superiority of mind to matter, and that the two are distinct, cannot believe that life, consciousness, and mind are products of matter; such persons, he thinks, if shown that there are strong reasons for supposing that man (as he exists on this earth) is the supreme product of the universe, will see no great difficulty in going a little further and believing that the universe was brought into existence for this very purpose, that is, for the sake of man.

I commend this striking passage to the careful perusal of my readers, for the *précis* I am endeavouring to put before them can scarcely convey an adequate idea of its eloquence and its force.

In reply to those who cannot understand how such a vast universe has been brought into existence, and yet so small a portion of it occupied by the one intellectual being—man—he suggests, as an illustrative argument drawn from the vegetable creation, the spores of ferns and the seeds of orchids, of which millions go to waste for one which reproduces the parent form. In the animal world, especially among the lower types, the same thing is to be seen. One cannot see the use of the enormous variety of species, or the vast hordes of individuals. For instance, there are at least a hundred thousand distinct species of beetles now existing; and in some parts of America mosquitoes are said to be so abundant that they sometimes obscure the light of the Sun. And when we think of the myriads that have lived during the long ages of geological time, the apparently useless immensity of life is brought home to our minds still more forcibly. "All nature," he says, "tells us the same strange mysterious story of the exuberance of life, of endless variety, of unimaginable quantity. All this life upon our Earth has led up to and culminated in that of man." Then in a passage which follows shortly, he asks, "Is it not in perfect harmony with this grandeur of design (if it be design), this vastness of scale, this marvellous process of development through all the ages, that the material universe needed to produce this cradle of organic life, and of a being destined to a higher and a permanent existence, should be on a corresponding scale of vastness, of complexity, of beauty?" I would call attention most particularly to the words at the commencement of this extract that I have last quoted, where the author introduces the word *design*, cautiously it is true, "if it be design," but evidently with a real meaning and intention; and I would ask, are they not remarkable words coming from the joint inventor with Darwin of the theory of evolution by natural selection? I do not mean that there is any necessary antagonism between the belief in a Providential design and the theory of natural selection moderately and reasonably stated; but one would scarcely have expected that one so deeply committed to this last-named system should have written not merely the passage I have quoted, but the whole elaborate argument leading up to it.

It is quite true that in his work on Darwinism, published some years ago, Dr. Wallace, while stating that he agreed with Darwin on the evolution of man, so far as his body was concerned, expressly recorded his dissent as to the human mind and intellect, which he maintained could not have been derived from an inferior type. In fact he said there were three things which no mere material process would account for: the commencement of organic life (even in its vegetable form); the first advent of conscious life (distinguishing the animal from the vegetable); and the mental powers of man, all of which must be ascribed to some spiritual influence. But even this would hardly have prepared us for the powerful argument drawn from the numerous and complex conditions of life upon this Earth, an argument directed no doubt to another conclusion, namely, that this is probably the only habitable world, but indirectly leading on to the almost inevitable inference of a Divine power, originating and influencing the whole course of nature. And I may recall to the minds of my readers that passage in which the author calls attention to the microscopic cells indistinguishable in their earliest stage from one another, yet belonging to totally different creatures, and possessing the power of reproducing and developing a perfect organism identical with its parents even in minute distinctive details (Chapter x.), as a remarkable illustration of this mysterious governing power, working by the ordinary laws of nature, and yet in a way which seems to baffle human intelligence.

I lay all the more stress on this important passage from the concluding chapter in our author's work, because I have noticed a tendency even amongst good Christians to shrink from reliance on the argument drawn from the apparent manifestation of design in the world around us in proof of the truths of natural religion. This may be due partly to the sneers of infidels at the argument when crudely stated; but perhaps still more to their own imperfect acquaintance with the mass of evidence that can be produced in its favour, so abundantly exemplified in the work I have been reviewing. For though the reasoning is directed to the proof of another point, yet it is none the less cogent. There may indeed be men who, without denying the facts as stated by our author, will attribute them to the fortuitous concourse of atoms; and if so I can only say I do not envy them their state of mind, morally or intellectually. But whether that be the case or not, I myself feel that the whole question of Providential design, and the evidence that science affords us in proof of it, may well be considered as possessing a higher interest for us than that of the existence of other inhabited worlds; for as to this latter subject no definite conclusion is possible, and I feel that there is some truth in the words which Professor Newcomb is said to have written in answer to a question of this nature—"the reader knows just as much of the subject as I do, and that is nothing at all." But though we can *know* nothing, we can weigh probabilities, and here my sympathies are with Dr. Wallace; and yet, supposing we were obliged to think otherwise, and to believe that there are intelligent inhabitants of other worlds, though our mind might be puzzled and our imagination bewildered, we might well leave the whole matter in the hands of the Almighty Being who created these far distant peoples as well as ourselves, and who would doubtless provide for them no less than for us; while nothing even so should shake the conclusion so justly to be drawn from the experience we have here around us of the workings of Divine Providence, to which indeed are due the orderly movement of the heavenly bodies in obedience to the great law of universal gravitation, and also, as Dr. Wallace has so ably and forcibly explained, the adjustment of the conditions of our life on this Earth, even to the finest and minutest details.

Dr. Wallace, before concluding, quotes the well-known passage from "Hamlet," beginning, "What a piece of work is man! How noble in reason! How infinite in faculty!" a well-chosen quotation, showing, as it does, that the complex argument of the man of science arrives at the same point as the intuitive judgment of the great dramatic poet.

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