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825TH ORDINARY GENERAL MEETING,

HELD IN COMMITTEE ROOM B, THE CENTRAL HALL, WESTMINSTER, S.W.1, ON MONDAY, FEBRUARY 6TH, 1939, AT 4.30 P.M.

R. E. D. CLARK, ESQ., M.A., PH.D., IN THE CHAIR.

The Minutes of the previous meeting were read, confirmed and signed, and the Hon. Secretary announced the following elections:—As a Life Fellow: Sir Frederic G. Keynon, K.C.B., D.Litt., LL.D. As a Fellow: Leslie James Moser, Esq. As a Member: A. R. B. Morrisby, Esq.; and as Associates: J. J. Young, Esq., A. P. Kelsey, Esq., Richard Allen, Esq.

The CHAIRMAN then called on F. T. Farmer, Esq., B.Sc., Ph.D., to read his paper entitled "The Atmosphere: Its Design and Significance in Creation"

The meeting was then thrown open to discussion in which the following took part: The Rev. Principal H. S. Curr, Mr. R. Duncan, Mr. H. W. Molesworth, and Dr. J. Barcroft Anderson.

Written communications were received from Miss C. M. Botley and Mr. E. L. Hawke.

THE ATMOSPHERE: ITS DESIGN AND SIGNIFICANCE IN CREATION.

BY F. T. FARMER, ESQ., B.Sc., Ph.D.

THE idea that the world consists of strata, lying over one another like layer upon layer of onion coats, dates back to ancient times. Aristotle held that the four elements, earth, water, air, and fire, always tended to move into positions one above the other and, after that, he was obliged to postulate not less than fifty-six concentric spheres in which the planets moved under unseen impulses.

Perhaps the human mind has a natural tendency to think in terms of cosmic layers; but whatever may have been the grounds for these ancient speculations, there is no doubt that they were on the right lines. To-day, we are all more or less familiar with the structure of the earth—it starts with a central iron-nickel core, followed by several distinct layers of rocks; after that there is the surface, consisting either of granite continents or oceans; then comes the atmosphere with its

Troposphere, its Ozonosphere, and higher still, its Kenelly-Heaviside and Appleton layers; and finally, situated an enormous distance away, there is believed to be yet another layer of electrons which move in tortuous trajectories about our planet like tiny rockets.

This afternoon we shall be concerned with but a part of this complex array of strata—the part that lies above our heads. We shall seek to discover the main facts about the layers which surround us day and night, and inquire how far they serve a useful purpose to man.

To tackle this problem it will be necessary, first of all, to pass in review the early stages of this world's history.

Much light has recently been thrown on this interesting subject, particularly by the advance of seismology and geology, and, as we shall see, it has a very important bearing on the condition and nature of the atmosphere now surrounding the earth.

To begin with, there is much evidence that the earth, together with the other planets of the solar system, was at one time ejected from the sun, or at least from a star occupying approximately the same position as our sun. It has been found, for instance, that the proportion of different metals (as distinct from the light elements) in the earth is practically identical with that in the sun.* Again, all the planets move round the sun in approximately the same plane, and this could scarcely have come about if they consisted of matter which had been captured by the sun from some other part of space.

Many views as to how the sun gave rise to the planets have been put forward, though we do not need to go into these in detail. One of the best known is that of Laplace, according to which "planetary rings" were formed as a result of the gradual cooling of the sun. But to-day this mechanism is not considered tenable as there seems to be no way in which such rings could condense to form the large planets of the solar system. It was to avoid this and other difficulties that Jeans put forward the now well-known theory that the planets were formed from a "filament" of matter which had been drawn out from the sun by the close encounter of another star. Calculation shows that if this star had moved past the sun fairly slowly it would have had time to transfer a large amount of angular

* V. M. Goldschmidt, *Journ. Chem. Soc.*, Apr. 1937, p. 655.

momentum to the filament. In this case the latter, instead of falling back into the sun, would have continued to rotate round it in an orbital manner.

The way in which such a filament of gaseous material would separate into individual masses has been examined in detail, and it appears that the theory gives a satisfactory explanation of most of the features of the solar system.

Yet it has turned out that even this view is not without difficulties. The chief of these is to account for the large angular momentum associated with the outermost planets, which seems to be much in excess of the predicted value. This and other difficulties can be resolved if we assume that the sun was initially a member of a binary system, and that the encounter of a third very massive star removed one of the pair, at the same time leaving a vast extension of matter from the remaining sun.

Whatever the exact details, however, it seems certain that the earth and other planets of our system were formed as a result of the collision of stars. We may proceed, therefore, to examine the subsequent behaviour of the hot filament of gaseous matter after it was thrown out into space and left to cool.

At first, heat would have been lost very quickly indeed; in fact, it is easy to show that after only a few years the planets must have begun to appear in a liquid form. This would be followed by a much longer period of cooling, probably of the order of a few thousand years, before the first solidification of rocks set in. The earth would then begin to take the form in which we know it. But, during this cooling process, important changes in the composition of the earth as well as of the other planets would be taking place; for since the outer layers of gas surrounding a planet consist of molecules, some of which have a proportion of energy much greater than the average corresponding to the temperature of the gas, there must of necessity be a continual escape of those molecules which happen to have sufficient energy to fly right out of the gravitational field in which they move. Moreover, since in a mixture of molecules of different kinds the light ones have just as much energy as the heavy ones, it is obvious that the loss will consist chiefly of those of the smallest mass.

Thus we should expect to find that the smaller planets, where the gravitational fields are weaker, would lose a large proportion of their light elements during the cooling process, while the larger planets would retain most of their original atmospheres. Calculation shows that this must indeed have been the case, and that the smaller planets, including the earth, must have lost the entire layer of light gaseous elements which would otherwise have remained surrounding them while the crust solidified. Jupiter and Saturn, on the other hand, which have much stronger gravitational fields, should have lost a far smaller proportion of their light elements during the cooling process. That this was in fact the case is strikingly confirmed by the known distribution of density between the planets. Although the volume of Jupiter is 1,300 times that of the earth, its mass is only 317 times greater. In other words, its mean density is less than one-quarter of the density of the earth despite the fact that pressures in its interior are very much greater. This can only be explained if we assume that both Jupiter and Saturn contain large proportions of hydrogen, helium, carbon, and perhaps other light elements which are relatively uncommon on the earth.

The planet Mercury, on the other hand, which has a mass of only one-twenty-third of that of the earth, is known to have no appreciable atmosphere surrounding it. This indicates that the gravitational field is too weak to retain any of the ordinary gases.

We have seen that the earth, by the time it had formed a solid crust, must have lost all the atmosphere which originally surrounded it. But we are now faced with the problem of explaining how the very considerable atmosphere which now exists could have come into being.

From the work of Jeffries* there seems to be no doubt that our entire atmosphere was liberated from the molten rocks during their solidification. The liquid magma contained quantities of dissolved gases which escaped as the temperature was reduced—just as they escape to-day in the lava lakes and during volcanic eruptions. In addition to the permanent gases, steam was evolved during the cooling of the earth—indeed, it is still evolved in huge quantities from volcanoes. Calculation shows that the primitive earth must have lost all its original water, together with the other gases, so that the whole of the water in the oceans must have been liberated from the molten

* *The Earth*, Camb. Univ. Press (1929). *Monthly Notes of Roy. Astr. Soc.*, Geophys. Supp., Feb. 1937.

magma. In conformity with this conclusion, recent measurements have shown that, under pressure, molten lava is able to absorb a very considerable quantity of water, which has the effect also of reducing its melting-point. A continuous liberation of steam must therefore have occurred from the crust of the primeval earth, and when the temperature fell sufficiently this must have formed first vast masses of cloud and finally the extensive oceans now in existence. The chief gases liberated as the result of volcanic action in the early age of the earth were, presumably, nitrogen, carbon dioxide and water vapour. Other more chemically active gases—such as ammonia, sulphur dioxide and hydrochloric acid (which provided the chlorine in the sea)—were rapidly removed when once the sea had condensed, leaving carbon dioxide and nitrogen as the chief constituents. Specimens of this early atmosphere, trapped in the form of bubbles in once molten rocks, have been analysed and bear out these conclusions. In addition, there is much geological evidence which leads to the same conclusion—thus the earliest sedimentary iron ores were deposited in the non-oxidised (ferrous) condition while, owing to the abundance of carbon dioxide, limestones could not be deposited until a later epoch.

Since the earth, even after solidifying, remained at a high temperature for a considerable time, it is obvious that its newly formed atmosphere must have tended to disappear into space by the process already described, although of course slowly. Thus a "sorting" of the atmosphere must have taken place; light gases, especially hydrogen and helium, which were almost certainly liberated with nitrogen and carbon dioxide, were thus lost completely into space, and it is probable that, were it not for this loss, we might to-day have considerably more nitrogen than we actually have.

It is of interest to note that considerable quantities of hydrogen and helium are still being liberated from the earth, and for a long time it was difficult to reconcile the known rate of issue of these gases with their very small concentration in the air. At first, it was supposed that owing to their extreme lightness, these gases were rising right through the atmosphere and forming layers on top. Observations on luminous clouds in the upper air showed, however, that this could not be the case since there was far too much turbulence for separation to take place.

In recent years the upper atmosphere has been the subject of extended research. It has turned out to be very different from what we had imagined, but newer conceptions make it easy to understand, not only the disappearance of hydrogen and helium, but also many other related phenomena.

To begin with, various observations—such as the measurement of the absorption of wireless waves—have shown that at a level of about 200 miles the atmosphere is at a very high temperature indeed, probably at least 1,000 degrees Absolute.* This is sufficient to cause a continuous loss of such light gases as hydrogen and helium from the earth, which easily explains why there is so little of them in the air.

It is obvious that this high temperature cannot be maintained by heat supplied from the earth, for it is far above that of the earth's surface. Moreover, we know that the air lower down is very cold, for direct measurements made with the use of balloons up to heights of about 25 miles have shown that the mean temperature at that height is considerably less than it is at ground level.

Thus, the great temperature must be maintained by some source outside the earth, and it is now known that the gases at these great heights are kept hot by their absorption of the sun's rays. As a result of this absorption large numbers of ions are formed, and it is these which are responsible for the ionised regions of the upper air which play so great a part in the reflection of wireless waves down to the earth.

By various methods it has now been found possible to obtain more or less reliable estimates of the temperature of the atmosphere at various levels, and the accompanying figure shows a graph in which all the data have been collected for heights up to two hundred miles.† From this graph it will be seen that at a height of about 90 km. (65 miles) the temperature is as low as 160 degrees Absolute, after which it begins to rise rapidly.

The temperature of the upper atmosphere is of no small significance from the point of view of living matter. Even at 1,000 degrees Absolute there is a slight escape of oxygen from the earth, and only a small rise would cause the removal of this element from our atmosphere altogether, and so make animal life impossible.

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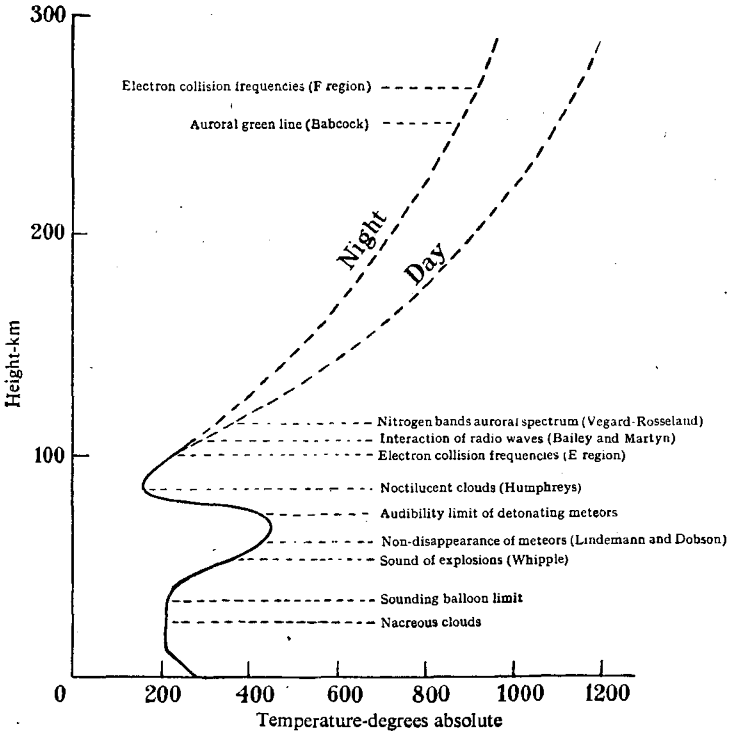
* D. F. Martyn and O. O. Pulley, *Proc. Roy. Soc.* A, **154**, 455 (1936).

† I am indebted to Messrs. Martyn and Pulley for permission to reproduce this figure.

Let us now turn to consider the changes which have taken place in the atmosphere since its first formation, and their relation to the existence of life on the earth. We have seen that after the sea had condensed, the gases which initially formed the atmosphere were in all probability carbon dioxide and nitrogen, no oxygen being present. This atmosphere, though very different from our own, is one which is entirely suitable for many



forms of plant life. It is now believed that in the early ages of the world the carbon dioxide was gradually used up by the luxurious vegetation which then covered the hotter parts of the earth, and that under the influence of sunlight it was slowly replaced by oxygen. In this way the world was gradually made suitable for the support of animal life. It thus seems reasonable to suppose that the stages of creation of life fitted in with this process of change in the atmosphere.

Up to the present we have been considering the atmosphere from a purely scientific standpoint. We have seen how the earth on cooling from a nebulous state lost vast quantities of gaseous constituents ; how it passed through a stage in which it had no appreciable atmosphere ; and how the present atmosphere came into being as a result of the liberation of gases from the molten rocks. We must now consider the question from a different point of view. Let us inquire whether the processes which have led up to the formation of our present atmosphere are the mere working of chance, or whether they are suggestive of design—perhaps the design of a Mind who had planned to make a world on which life could exist.

In seeking to reach a conclusion on this question, we are naturally confronted by certain difficulties. It can be argued, for instance, that there is nothing significant about a world in which the conditions are suited for the support of life : for if the conditions on the world had been different from what they are, the forms of life on it would have been correspondingly different.

This point of view is very plausible, but, unfortunately, there is no space to give it detailed consideration in this paper.* However, we may notice a few important points which are relevant to the issue. In the first place chemical considerations indicate that the choice of basic elements which are capable of forming pliable compounds, such as our bodies are composed of, is very limited. It appears, indeed, that, apart from the very exceptional properties of carbon in forming long chainlike molecules, such structures could not be formed at all.

This at once sets a very definite limit to the temperature range at which life might be able to exist ; for it is only over a very restricted range of temperature that carbon compounds are stable. Other considerations, moreover, make it fairly certain that living matter can only exist within the range of temperature at which water remains in a liquid state. It is now nearly a century since Whewell pointed out that the earth is one of the few planets that has a temperature lying within these limits, and since that time it has become increasingly clear that the question of temperature alone sets a sharp limit to the possible existence of any kind of life.

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* See N. V. Sidgwick, *Science*, **86**, 335 (1937).

By itself, the fact that the earth is at the right average temperature for life is nothing remarkable; if the earth had not fulfilled this requirement, it is likely enough that another of the planets would have done so. But it is just here that other factors essential to the existence of life become significant. In order that living creatures should be able to exist and move about from place to place on the earth, it is obvious that they must have available some source of energy. Although energy can be obtained in other ways than by the absorption of oxygen to react exothermally with carbon compounds, it is not easy to find any other reaction which would meet all the requirements. Indeed, a chemically active constituent in the atmosphere seems to be essential if creatures are to gain a continual supply of energy without being tied to one place on the earth. Thus the presence of an atmosphere containing a proportion of oxygen becomes a factor of great importance—and incidentally oxygen is absent in the atmospheres of all the other planets. The process by which this oxygen came into being has already been considered; but we may well inquire whether it was a necessary feature of a planet situated at our particular distance from the sun. Would there, for instance, have been any oxygen if the earth had happened to be of a different size?

We have seen that the rate of escape of gases into space depends very greatly on the gravitational field of the planet. If the mass of the earth had been somewhat smaller, therefore, instead of the oxygen escaping slowly, as it does at present, it would have escaped rapidly all the time, and in all probability there would have been a negligible proportion of it left in the air. This alone would have destroyed the possibility of animal life, as we have seen.

Suppose, on the other hand, that the earth had been larger than it actually is. We know that in this case the proportion of light elements which escaped from the planet while still in the gaseous state would have been very much less, and a proportion of the original atmosphere would have remained round the planet throughout the cooling period. The resulting change in the composition of the earth's atmosphere would have been very great. It would have contained vast quantities of hydrogen and helium, and the presence of the former would have made the existence of free oxygen impossible, besides making the atmosphere very much more dense. Observations made recently on the large planets Jupiter and Saturn have shown that they are surrounded by enormous atmospheres; indeed, according to the best estimates available, nine per cent. of Jupiter's and twenty-three per cent. of Saturn's radius consist of atmosphere. Although these values may not be accurate, it is easy to see that if they are of the right order of magnitude the pressure at the base of the atmospheres must be many thousands of tons to the square inch, which would obviously render life in any ordinary form quite out of the question. Secondary effects of such an increase in pressure would also be extremely marked. For instance, turbulence in the atmosphere, instead of taking the forms of winds such as we experience on the earth, would be violently destructive, and probably eliminate any vegetation on the planet. Another effect even more serious to the existence of life would be the almost complete absorption of radiation from the sun in such an atmosphere. This would deprive the living matter of its primary source of energy.

A further feature of the earth highly dependent on its size is the proportion of its surface covered by water. In its present state the sea covers four-fifths of the total area and a relatively slight increase in its gravitational field would have caused a sufficient proportion of light elements to remain to result in the whole surface being covered. The possibility of marine life would, perhaps, have remained; though even this is doubtful when the influence of vegetation and land life on the ocean is taken into account.

From these considerations it is obvious that the ability of the earth to support life depends on many features besides its mere location in the temperate region of the solar system. Other factors, such as those which we have been considering; and also others again which we cannot consider here, such as the length of day and night and the inclination of the earth's axis to the plane of its orbit, have all a fundamental bearing on the possibility of life on the planet.

When we view all these factors together, it becomes apparent that the existence of life on the earth is far from the natural result of its position in the solar system, as we might at first sight suppose. Rather, the whole set of conditions, which make our very existence possible, is so out of the ordinary that if we will not recognise any purpose in the universe, we must surely describe them as a *freak*. Not only is the existence of our solar system almost a unique feature of the universe, but the earth itself shows still further signs of having violated the laws of probability in becoming an abode for living creatures.

But at the present time there is less and less need to speculate along such lines. When we view these features of our earth scientifically the hypothesis that the earth is the outcome of a chance evolutionary process from chaos becomes less and less credible. The more science shows us of the structure and history of our world, the more do we see the evidences of design and purpose on every hand. The earth's atmosphere which we have been considering this afternoon is but one of many cases where closer inquiry shows the handiwork and forethought of God in place of the cold working of chance.

Discussion.

The Chairman (Dr. R. E. D. Clark) said: Dr. Farmer has mentioned, I am afraid all too briefly, a number of topics which are of absorbing interest at the present time. Among these are one or two which I should like to single out for comment. To begin with, there is the rather surprising discovery that the steam which later formed the oceans issued first of all out of the molten rocks. Now it may have occurred to you to wonder what was the future history of this steam. So let us try to piece the story together.

At first the atmosphere consisted chiefly of hot, dry steam together with some carbon dioxide and nitrogen. Its pressure near the surface of the earth must have been very high— comparable, in fact, to the pressure in the depths of the oceans—while no light from the sun pierced the thick blanket of gases. By and by, as the earth cooled, there came a time when the critical temperature of steam was reached—the temperature below which highly compressed steam becomes a liquid.

When this happened the oceans began to condense. But the process must have taken place in a very remarkable way. In the first place the earth was still cooling from the outside. This means that the steam high up in the sky must have reached its critical temperature before that lower down, so that for a time a layer of water was actually left floating on the steam below. But as this state of affairs is unstable at the lower surface where the water and steam meet, there must have been violent convection currents, as a result of which the temperature tended to be equalised. This would cause the oceans slowly to descend to the ground.

Even after the oceans had descended to the earth they must have been in a state of violent commotion. When liquids condense near their critical temperatures there is, at first, very little difference between the densities of the liquid and the vapour. So during the period of condensation the condensed water must have been in constant agitation. Disturbances which to-day would make waves a few feet in height would then have raised gigantic walls of water, hundreds, and perhaps thousands, of feet high. The moon, then nearer to the earth than now, would have had a correspondingly greater influence, and it is probable that at one stage the continents were periodically covered and uncovered by water. Then again, with heat still escaping from the earth, the boiling cauldron of waters would in places be turned to steam, so that great pockets of vapour would be produced in the oceans, covered by liquid at a higher level. Indeed, an onlooker might never have guessed that water tries to find its own level!

Such, so far as we can tell to-day, must have been the story of the sea at its birth. And it is interesting to compare it with the brief description of those days given to us in the first verses of Genesis. Here we read that there was a waste and a void, and that darkness was upon the face of the deep. In that darkness the Spirit or Wind of God moved upon the waters. Now, elsewhere in Genesis we find the words "of God" are used to convey the meaning "very great": thus in Genesis xxxv, 5, a great terror in certain cities is spoken of as a "terror of God." From this it would seem to follow that the Genesis passage is intended to convey the idea that a *very great* movement of the waters took place at this time. But however this may be it seems fairly clear that the writer is talking of some mysterious moving of the waters before the light had penetrated to the surface of the earth.

Moreover, the writer of Genesis correctly puts the separation of the dry land at a later stage, and is undoubtedly correct in several other geophysical details he gives us, though in one or two there is still doubt from a strictly scientific standpoint. So here, within a few verses, there is a remarkably accurate account of what happened. Moreover, it is hard to see why anyone should mention the violent commotion of the waters at all, without possessing a knowledge of the critical states of liquids. To my mind, the extraordinary accuracy of these early verses of the Bible constitutes very real evidence that the critics are not right in assigning them to the products of ordinary human intelligence. The traditional view of the Bible seems to be more in keeping with the facts.

Dr. Farmer has also alluded to the coming of oxygen into the atmosphere. The reaction by which the green leaf makes oxygen is one of remarkable complexity. Some years ago Molisch found that certain leaves, when moistened with water and put in the sun, could be made to evolve oxygen. But subsequent research has shown that neither under these, nor any other known conditions, can a dead plant be made to produce oxygen from carbon dioxide in sunlight. Indeed, quite a small injury often stops the entire photosynthetic activity of a plant. Furthermore, although a large number of autotrophic bacteria (sulphur bacteria, iron bacteria, etc.) are known, not one of them possesses the power of making oxygen, although some of them (the purple bacteria, etc.) can obtain energy from sunlight.

These discoveries are of some interest in view of the common evolutionary idea that life started as very simple organisms in the sea, and gradually got more complex as the years passed by. As none of the simplest organisms can make oxygen, and all are in fact dependent on oxygen for their existence, it is difficult, as Jeffries points out, to see how life could have evolved from unicellular organisms at all. Indeed, it would seem from this evidence alone that green plants must have been the first forms of life. If subsequent research confirms this view it will add yet a further confirmation of the truth of the simple narrative given in Genesis.

J. B. S. Haldane has attempted to avoid this difficulty by suggesting that large quantities of proteins were first formed in the sea by the action of sunlight upon water, carbon dioxide and ammonia, so that a suitable environment for the first living cells was made available. That is not an unreasonable point of view—if only proteins could come into being by such means. The fact that no reputable research worker in the last twenty years has claimed to make a trace of protein in this way suggests, however, that they are not produced by photosynthesis. (A claim to make amino-acids was made by Baly soon after the war, but it is generally regarded as mistaken.) I think, then, that we may disregard Haldane's view, together with his further opinion that the sun's light made proteins in such abundance that the sea became " as thick as soup " with them, and the protein molecules, now able to collide frequently, formed the first living matter by chance! (*Fact and Faith*, 1934 ed., p. 45.)

There is one more thing I should like to say. Dr. Farmer has placed a good deal of emphasis on the remarkable plan of the world. The way in which this apparent "design" is becoming more and more obvious as research progresses is certainly very significant. The idea that a correct theory is one which fits the facts of subsequent discovery is a principle which lies at the basis of materialistic philosophy; yet it is now transpiring that materialism fails when judged by its own criterion. According to materialistic philosophy, the subsequent trend of discovery ought to be one in which the apparent " freakishness " of the world becomes less and less as new discoveries are made. But the very opposite is happening to-day. Everywhere the unexpected seems to have taken place in the world of nature, and modern research merely goes to multiply examples. This being so, it is surely increasingly clear that the world cannot be explained on the basis of a materialistic philosophy.

Well, perhaps I have occupied too much of your time already. I am sure you will all desire to join with me in giving a hearty vote of thanks to Dr. Farmer for his valuable and stimulating paper.

The Rev. Principal H. S. Curr said: I have thoroughly enjoyed Dr. Farmer's paper, not because I can lay claim to specialised or even general knowledge of the subject, but rather due to his admirable methods of exposition which made a subject of considerable complexity to be full of interest. None of us, perhaps, with the exception of our distinguished Chairman, appreciates how abstruse Dr. Farmer's subject has been. If we had tried to read it up in scientific books, the task would have been found to be no easy one.

I should like to advance the suggestion that an interesting point might have been made by the lecturer, if he had referred to the dimensions of this planet, on which man lives, and moves, and has his being in comparison with those of the other stellar bodies. Sir James Jeans was reported in the Press to have stated in a lecture that, in comparison with the astronomical scheme of things, the globe on which we dwell for " life's little day " is no larger than a grain of sand in comparison with the bulk and distance of other galleons voyaging in the seas of space. When Dr. Farmer's very interesting conclusions regarding the suitability of the earth for man's life are placed side by side with these estimates of its relative magnitude, one marvels and feels constrained to apply to our world the words of Micah with reference to Bethlehem, destined to be the birth-place of Our Lord and Saviour: " But thou, Bethlehem Ephratah, though thou be little among the thousands of Judah, yet out of thee shall he come forth unto me that is to be ruler in Israel; whose goings forth have been from of old, from everlasting " (Micah v, 2). The earth may be amongst the least of the stars in size, but in other respects it takes precedence before them all since quality is ever superior to quantity.

I wish particularly to make some observations with reference to the bearing of Dr. Farmer's conclusions on the ancient argument from design as a proof of the Being and Excellence of God. He himself claims in the concluding sentences of his paper that he has furnished additional evidence for the validity of that phase of apologetics. Need I remind you what the argument from design is. It has never been illustrated more effectively than in Paley's famous analogy of the savage and the watch. He pictures a barbarian of considerable intelligence finding a watch for the first time. As he examines this remarkable combination of wheels and levers and springs, he concludes that its maker must have been an individual who was much more clever and ingenious that he could ever hope to be. In the same way man finds himself in a world where the adaptation of means to ends can be his daily delight and despair if he have but eyes to see, and a mind to perceive. The earth is full of the glory of God Who has made all things in wisdom and power and love. Dr. Farmer has provided fresh proofs of that inference, and these are as persuasive as they are novel.

While I yield to nobody in my reverence and admiration for the argument from design, I wish to point out that its effectiveness is limited. As a logician of great eminence observed, we can never be sure that these marvellous aptitudes and adaptations which abound both in animate and in inanimate nature, are not the result of chance. That may only be one in a million, or in astronomical figures, but it is still a possibility. It may be improbable, but it is not impossible. While I welcome the remarks made by the Chairman that all suggestion of what he describes as seeming freakishness is tending to disappear from scientific theories regarding the origin of the universe, I fear that it is necessary to sound a note of caution by a reminder that certitude cannot be obtained by such inductive methods.

That brings me to refer to the clamant need of revelation. Neither by search nor research can man find out God. Unless His Maker manifests Himself to His creatures in a more sure and personal and direct way than by the evidence of what has been created, man is condemned for ever to grope after God if haply he may find Him. It is the privilege of the Institute to bear witness to the truths of revealed religion as contained in the Living Word and the Written Word. In the light which streams from these supernatural sources, all things become new, and old things pass away, and one of these things most surely established by this method is the saying of the Psalmist that " the earth is the Lord's, and the fulness thereof; the world and they that dwell therein. For He hath founded it upon the seas, and established it upon the floods " (Psalm xxiv, 1–2).

Mr. W. H. Molesworth said : It is difficult to understand how a high temperature zone such as is referred to on page 43 could accumulate heat, since it only faces the sun for a short part of the day, unless its outer surface is always in contact with a substance of still higher temperature and density.

Written Communications.

Miss C. M. Botley, F.R.Met.S., wrote : Dr. Farmer's paper is so lucid and so well planned that comment seems superfluous except to congratulate him upon the way he has presented his thesis. One or two thoughts, however, occur to me.

(1) The high temperature of the upper air may be designed partly as " Air Raid Precaution." Lindemann and Dobson, in their

classic paper, have shown how it would facilitate the dissipation of meteors which otherwise might be rather troublesome to us below.

(2) The statement that oxygen is absent in the atmospheres of all the other planets is perhaps a little too sweeping, for there is the possibility that the atmosphere of Mars may contain it in small quantities. I think it is certain that there is vegetation on Mars, though that can exist in the absence of free oxygen, *e.g.*, anerobic bacteria.

Mr. E. L. HAWKE, M.A., F.R.A.S., Secretary R. Met. S., wrote: I have read Dr. Farmer's paper with much interest, and consider it an excellent treatment of the subject.

It always seems to me that the majority of astronomers and physicists put an unnecessarily limited interpretation on the word "life." Personally, I share Sir Oliver Lodge's conviction that the entire universe is "pulsating with life" not, of course, as *we* know it; and I can see no reason why any environment whatsoever should be regarded as incapable of forming the seat of the particular sort of life that is appropriate to itself. May we ourselves not be likened to minute organisms inhabiting one apple growing on one tree in an orchard of enormous extent? We can see some of the other trees (perhaps most of them with the most powerful telescopes), but have the presumption to doubt whether any of them has produced an apple crop, and, if it has, whether organisms, even of an entirely different nature from our own, can exist on more than a very small minority of the apples. This is clumsily put, but no doubt you will get my meaning.

By the way, have you ever come across the following remarkable passage from the works of that strange and now largely forgotten essayist of the Victorian age, Ambrose Bierce? It was written long before Einstein's time: "Magnitude being purely relative, nothing is large and nothing small. If everything in the universe were increased in bulk one thousand diameters, nothing would be any larger than it was before, but if one thing remained unchanged, all the others would be larger than they had been. To an understanding familiar with the relativity of magnitude and distance, the spaces and masses of the astronomer would be no more impressive than those of the microscopist. For anything we know to the contrary, the visible universe may be a small part of an atom, with its component ions, floating in the life-fluid (luminiferous ether) of some animal. Possibly the wee creatures peopling the corpuscles of our own blood are overcome with the proper emotion when contemplating the unthinkable distance from one of these to another." I think there is much food for thought in that.

AUTHOR'S REPLY.

I am much indebted to our Chairman for the valuable contribution he has made to this subject. He has given us an illuminating picture of the early stages in the development of the atmosphere, and shown the remarkable accord that exists between this development and the historical account in the early chapters of Genesis. It is unnecessary for me to elaborate the points he has made, except that I would like to draw attention to an interesting result which has recently emerged from a study of the upper atmosphere by means of wireless waves. It has been found by careful measurements that tidal movements exist in the high regions of the atmosphere and, at a height of some seventy miles, these have an amplitude of as much as half a mile. This has an interesting bearing on the Chairman's view that the primitive atmosphere exhibited vast tidal disturbances (actually moving in the opposite direction to the tides with which we are familiar). As he pointed out, the atmosphere containing water at about its critical temperature represented a state of affairs in which slight changes in gravity must have had a profound effect, and the relatively large movements which are now known to take place in the upper air make the tides he has described seem less startling than would at first sight appear.

Principal Curr has drawn attention to the essential uncertainty of the inductive method of reasoning as a means of finding out the truth about nature. His argument is doubtless correct, though to discuss the question adequately would take us too far from our subject. It is essential to realise that to the scientist, as indeed to any inquirer into nature, all knowledge suffers from this drawback. However sure we may feel of the correctness of certain laws of physics, such, for example, as the law of gravitation, we are bound to recognise that the experiments upon which they were based may ultimately have happened to be " freaks," and so given rise to a misleading interpretation of the phenomena. It would be futile, however, to discredit all knowledge on this account; our duty as scientists is surely to use the reason given us to the best advantage and make the most reliable inductions possible. To deny the value of induction is to close the door to any further knowledge, a course which cannot be considered as God's purpose for man. It is, of course, true that revelation often gives us a certainty where we might otherwise be in doubt. But this certainty, while satisfying to the Christian, can never carry conviction when we seek to give a reason to others for the " faith that is in us."

Mr. Molesworth's inquiry about the way in which a high temperature may be maintained in the upper atmosphere when the sun's influence is removed, may be answered without much difficulty. In the rarefied gas which we are considering hot molecules are dependent primarily on the process of radiation for dissipating their heat energy. The energy they receive, however, is due to ultra-violet light from the sun and after absorption a large part of this degenerates slowly into thermal energy, thus raising the gas to a high temperature. Now, large molecules such as are common on the earth are able to re-radiate thermal energy readily, but this is not the case with the atoms and small molecules of the upper atmosphere. The result is that when once the energy has fallen to the thermal level it can only be dissipated very slowly, and a high temperature may be maintained even though the source of energy is absent for long periods.

Miss Botley raises the point that the high temperature in the atmosphere may be vital in safeguarding us from bombardment by meteors. It is true that in a hot gas meteors are dissipated more rapidly than in a cold one; but it seems doubtful whether the high temperature we have been considering can be of importance in this connection since it occurs at a height considerably greater than that at which the dissipation of meteors takes place. The high-temperature zone exists only above about 120 miles from the earth, whereas meteors first experience sufficient air density to cause evaporation at heights of the order of 90 miles. It would appear that the atmosphere would have to be hot down to much lower levels to permit this factor to be of importance.

With reference to the possibility that oxygen exists on Mars, the only evidence appears to be the red colour of the planet, which is interpreted to mean that iron compounds have been oxidised on its surface. This gas may have been present in the early history of the planet, but recent measurements show that its concentration is less than one-thousandth of that in the earth's atmosphere, if indeed there is any at all. (*See* W. S. Adams and T. Dunham, *Astrophys. Journ.*, **79**, 308 (1934).) The evidence for vegetation does not seem very weighty, for there are other possible explanations of the change in colour of the planet with the seasons. An excellent popular account of this interesting subject will be found in Dr. R. E. D. Clark's recent book, *The Universe and God*, p. 63 ff.

I should like, in conclusion, to express my thanks to all those who have contributed to the discussion this afternoon.