JOURNAL OF

# THE TRANSACTIONS

OF

# The Victoria Institute

OR

## Philosophical Society of Great Britain

VOL. LXXIII

**1941**

LONDON:

PUBLISHED BY

THE INSTITUTE, 1, CENTRAL BUILDINGS, WESTMINSTER, W.C.1

## 843RD ORDINARY GENERAL MEETING.

HELD IN COMMITTEE ROOM 19, LIVINGSTONE HOUSE, BROADWAY, S.W.1, ON MONDAY, MAY 12TH, 1941, AT 6 P.M.

DR. JOHN AITKEN IN THE CHAIR.

The Minutes of the previous meeting were read, confirmed and signed.

The CHAIRMAN then called on Dr. F. T. Farmer, B.Sc., Ph.D., to read Dr. Sutherland's Paper entitled "Inanimate Nature: Its Evidence of Beneficent Design."

The Meeting was thrown open to discussion in which the Rev. A. W. Payne took part.

Written communications were received from Dr. W. T. Marshall, Rev. Principal H. S. Curr, Dr. R. E. D. Clark, and Brig. N. M. McLeod.

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# *INANIMATE NATURE.*

## *Its Evidence of Beneficent Design.*

BY BRIAN PORTER SUTHERLAND, M.SC., PH.D.

(*Gunning Prize Essay*, 1940)

THE subject of design in nature and the evidence it affords of the working of an intelligent Designer and Creator have been dealt with in several papers already presented before this Society. Some early papers have considered the metaphysical aspects of the subject and others have brought forward evidences of design, order, and beauty in various realms of nature. Again, the argument from design has been not infrequently a basic consideration in other papers dealing with a variety of natural studies. However, our present subject covers a field to which recent discoveries in science have made important contributions, and with the more specifically defined approach it should be possible to present a useful study.

Although the general philosophy of the "Argument from Design" is beyond the scope of our present paper it may not be amiss to mention briefly the chief points in it. Basically we must assume the existence of mind, particularly our own mind, independently of matter. If with this basic assumption we examine a particular object, phenomenon or a group of such and find therein that which unmistakably points to order, design, beauty, or arrangement, we argue that behind these there must be an intelligent mind.

The arguments urged against this conclusion are mainly along two lines. The materialist refuses to admit our basic assumption. Thought, for him, is but a secretion of the brain. Everything is due to mere chance. A major difficulty of this position is that the very argument disposing of mind is entirely without meaning except to an intelligent mind. Others such as Kant, while admitting the assumption of the separate existence of mind, have refused to allow the analogy of reasoning from the known existence of a controlling mental force in ourselves to that of such a force in nature. The refusal has been made on the ground that such an analogy cannot be proved to hold when comparing the finite and the infinite. Kant's objection is disposed of when the meaning of the word "infinite" is made clear. For the purpose of the argument from design at least, "infinite" is definitely not to be taken as implying that the mind behind nature is essentially different in kind from our own. Broadly considered, in spite of the great advances in knowledge in all spheres, in spite of the reasonings of later philosophies, the main lines of logic of Paley's "Natural Theology" still stand, the argument from design is still valid.

Our present subject is limited to inanimate nature and the term will be taken with the narrower meaning, not extending it to vegetation as is sometimes done. This limitation has some important effects on the main lines of argument.

When dealing with living beings we may find that study leads to the belief that a certain structure is definitely fitted to serve for the good of the being itself. If so, we will say that we have in this an example of beneficent design. However when dealing with inanimate nature the good of the object itself cannot enter into the consideration, but evidence of beneficent design must be sought in facts which show that inanimate nature has been planned for the good of living nature. Generally for this purpose living nature will be considered in its wholeness, for it is indeed more than a collection of individual organisms. In some cases, however, there is a conflict between what might seem best for one kind of organism as against another. In these we shall expect that beneficent design will be shown in that which favours the higher type. Ultimately many phenomena are to be viewed as in relation to the good of man, although it is obviously ridiculous to attempt to argue every case in this way, except in so far as we may say that anything which shows the power, wisdom, or goodness of the Creator is good for man as it serves to reveal God to him.

This last point may well be briefly considered a little further here, invoking the aid of Holy Scripture as our guide. For though an appeal to the Bible may not convince the sceptic in such a study as this, yet it will be a help to us as believers in giving us a true perspective.

As revealed to us, God's main interest and purpose for this world were in its being inhabited.[1] From the beginning He appointed vegetation as food for every beast of the earth and every fowl of the air and every thing that creepeth, and He saw that the arrangement was good.[2] In His answer to Job's complaint God declares that He provides the ravens with food[3] and He gives the peacock its beauty.[4] It is declared elsewhere that not a sparrow falls to the ground unnoticed.[5] However, of man not only is it declared that his food is provided in the vegetation, but that to him was given dominion over all other living things together with the work of subduing the earth.[6] It is further stated that he is of more value than many sparrows.[7] This exalted position of man was not primarily for his own comfort or convenience but rather that he might use it to gain the likeness of God in whose image he had been made and that in harmony with a subject and contented creation he might bring about the fuller glorification of God. Nearly, if not all, of the present vanity and apparent futility in nature is to be traced to man's failure, and the Christian hope includes the assurance that this is to be entirely remedied when man reaches his destined place of manifest sonship to God.[8]

This leads us to a difficulty that has been raised against the argument from design, namely, that not infrequently the happenings in inanimate nature seem anything but beneficent to man. The crushing hailstorms that ruin miles of harvest fields, the tornadoes that devastate the islands of the sea, the earthquakes that spread destruction and death, how may these be brought into harmony with the idea of a beneficent Creator and Providence ? And besides these outstanding phenomena, what of the lesser occurrences that bring so much trouble, discomfort, and suffering ? Admittedly there are these difficulties. Admittedly there is also very much about nature that, though not harmful, is apparently purposeless. But let us also admit that even in the realm of the physical and material, in the realm that rightly belongs to science, we know but a small part. Undoubtedly further study will show the value and purpose of much that is as yet inexplicable. And after all, we know that there is more to be gained than material plenty and physical comfort ; there are those values for which life itself is worth sacrificing. We can learn much through the seeming opposition of nature, and we can believe that the " acts of God " which bring present loss are with a view to greater gain. Should there be those who are not ready to admit even this, we can certainly affirm, without fear of contradiction, that in the main, Providence is benevolent and that the charge for by far the greater part of the suffering in the world is only too evidently to be laid to man's inhumanity. It is to be hoped that this essay will support the first of these contentions at least.

But to return to closer consideration of our immediate subject, we need to mention one other general point in connection with design in inanimate nature before proceeding to the detailed study. This is the question of adaptation. Obviously, if a particular condition in the world is suited to the requirements of living creatures the adaptation, if any, cannot have been done by the inanimate. It is, of course, admitted that for all we know now there are many conditions in the inanimate world that could be changed, and with comparatively little major difficulty or adaptation, living beings could adjust themselves to the changes. For example, a healthy person can easily become acclimatised to the rarefied air of moderately high altitudes so that we cannot say that from the point of view of human respiration our particular normal pressure and oxygen content of the air are an evidence of design. We can readily imagine animals proportioned to live with comfort and convenience in an atmosphere with quite a different pressure of oxygen. However, it is different when we try to imagine life on a planet with an atmosphere say of nitrogen or neon.

We submit at the outset that when inanimate nature exhibits a comparatively complicated, abnormal, or unexpected behaviour or condition, and when this dovetails precisely into the requirements of living beings as we find them here, then such is an evidence of beneficent design. It is not necessary to prove the absolute impossibility of another kind of life being able to exist under quite another set of conditions. In fact we know so little of the possibilities even in this universe, so little of life in the ultimate, that proof of such impossibility is beyond our reach. Therefore, although some aspects of this question will be dealt with later, we will in general restrict our consideration to life as manifested through material organisms of the same general order as that we are familiar with. Living beings might exist in the sun, but life could not be manifested under conditions there in any way resembling the physical manifestations of our present experience. We look to find then, in our consideration of inanimate nature, not self-adaptation, but the evidence of beneficent foresight and planning for the good of living creatures, making possible a life of usefulness and happiness for man and leading ultimately to his spiritual welfare as he is brought increasingly to the knowledge of God.

The field of inanimate nature is so vast that in a study of this kind it is difficult to know the best means of approach, how much can be taken for granted with special mention and to what extent the most fundamental phenomena are evidences of design. Perhaps the first essential to be mentioned is that, for any reasonable kind of development, the universe, and particularly that part with which we are mainly concerned, must be designed on a basis of law and order, constructed of materials whose properties do not change, which will always behave the same way under the same conditions. Further, it is evident that there must be a unity about the different kinds of materials; they must all obey certain fundamental laws, or it is difficult to conceive how a stable cosmos could exist except in a condition approaching dead uniformity.

On the other hand, while a unity is necessary, the materials must be such as to allow of a diversity of structures being formed therefrom, which will have their own peculiar properties and yet show a good measure of coherence and stability in the general system. It is hardly necessary to say that this is the case. There are almost numberless kinds of materials possible under conditions such as on this earth, yet all obey certain basic laws in precisely the same way. That this is so is patent from the fact that physics, at least in its fundamentals, takes no account of the chemical or biological nature of material. The laws of motion, the laws of thermodynamics, the law of gravitation are true for all matter whether grains of sand or mountain ranges. Even the fact, if it be a fact, that under conditions such as exist in certain stars, the laws of conservation of energy and of matter no longer hold, does not alter the argument. Under such special conditions different behaviour is not unexpected and does not affect the fact that the universe, and above all that part that vitally concerns man, has been designed and constructed on fixed and uniform laws by virtue of which alone its ordered stable state is possible.

It is further evident that for anything like the amazing diversity of development that has occurred, particularly in animate nature, there must be provision for the formation of a vast number of structures within the one main framework and with a comparatively limited number of basic materials. An artist may have in one picture a hundred different shades of colours, but he may only have used half a dozen separate pigments. It would be quite impracticable for him to have a ready supply of every shade he would ever need. So it seems that only in some such way would be practical the existence of the remarkable variety and fulness of development that is found in life on this sphere. It seems necessary that there should be a supply of a comparatively small number of basic materials, but these must have the properties of being capable of combination in a great many ways. Also, in order to provide for a succession of growth, progress and development, there must be means whereby the limited supply of basic materials can be used over and over again in new and different ways. This seems precisely the scheme upon which our world has been designed. The globe itself constitutes the supply of basic materials, the chemical elements. (Their nature and extent will be considered later.) The constant flow of energy from the sun fundamentally supplies the means needed to bring about the combination and re-combination of these elements to form the great number of compounds used to support and manifest life. Obviously the energy so supplied must be capable of bringing about these changes. It must have a suitable potential and intensity, using the words in a general sense. On the other hand, conditions must not be such as will make the existence of these compounds impossible. For example, the sun has its own source of energy. What it is need not now concern us. But the energy conditions in the sun, or as we usually speak, the temperature, is so high that the chemical elements cannot remain in combination to any extent at all sufficient for the purposes of living beings. It, therefore, seems best, if not entirely necessary, that our earth should be provided with an external source of energy at a temperature much higher than its own. The solar system in its essential features is thus evidently particularly fitted for the home of life.

Perhaps equally fundamental and equally giving evidence of design are the basic physical properties of matter. For general stability, and particularly for that of a planetary system, matter must possess inertia. Furthermore, matter must be capable of storing energy. Energy may be simply described if not precisely defined as accumulated mechanical work. Matter shows in a great variety of forms and way, the property of receiving this accumulated work and holding it either statically as potential energy or in movement as kinetic energy. It is possible for the store of work to be kept indefinitely in many forms without appreciable loss and yet for the store to be made available for work again. This may seem very obvious and not at first sight an evidence of design, but surely it is. To use the mechanical illustration of the storage of water at high levels in suitable reservoirs with valves to allow its flow as needed, we might say that nature has been designed with an enormous number of possible and actual energy reservoirs. The sun pours out his stream of energy, but it does not by any means all run down at once to one uniform level. By various agencies, and particularly by living ones, energy is stored at high levels so as to be available for work if the right valve can be opened. To give an example in the chemical realm, there is a very strong tendency for carbon, as in coal, to combine with the oxygen of the air. The two elements have a chemical affinity, but under ordinary conditions the coal may lie out in the air for years and practically nothing happens unless a fire is started by applying intense energy. This phenomenon is described by saying that to allow the reaction between carbon and oxygen to proceed, a certain energy of activation is needed. Once well started, the burning supplies this energy so that the action is continuous. There is no need to labour the point, but it is evident that if matter did not have properties to allow it to store energy, life could never be manifested in a material world, and it is by no means obvious that matter must be so except as designed and ordered by an intelligent Creator.

At one time the idea was prevalent that many, if not most, of the stars were centres of systems similar to the solar system, each with its series of planets. However, it has been difficult for astronomers to account for the formation of planetary systems under what are considered ordinary conditions. According to the theory perhaps most favoured at present, that the solar system originated by the close approach of two stars, very few indeed of the stars, possibly one in a million, have planets at all. The possible abodes of life are therefore very restricted, the more so as by no means all planets can support life, as we shall see.

A planetary system capable of supporting life must in the first place be stable over long periods of time both as to the matter available on the planet and the supply of energy from the star. In the solar system these conditions depend to an important degree upon the properties of what is commonly called the ether. This is the medium filling all space and serving for the transfer of energy across open space. The force of gravity whereby the relative positions of the sun and earth are maintained is conveyed by the ether, so also is the radiation which constitutes our steady supply of energy from the sun to the earth. This medium, ether, must exert no frictional drag on matter, else the motion of the earth would be retarded and eventually the earth would fall into the sun. It must also be transparent to radiation. Actually radiation is transmitted entirely unquenched, undispersed and undiminished by the ether. No friction nor viscosity can be detected in it. It dissipates no energy and generates no heat. Yet it conveys the enormous forces of gravitation and indeed ultimately is the vehicle for all mechanical and electrical force and chemical affinity. This combination of properties is so remarkable that it is almost unimaginable were it not actually the case, and the argument is not affected if we prefer to speak of space rather than ether. The properties are such as to give the required effect, the nature of the means used is unimportant for the present purpose.

The stability of the planetary system is also dependent on the motion of the planet. It is beyond question that the earth moves in its orbit round the sun and that this motion is continuous and unabating. How it first received the impulse necessary to start this motion is not so clear, but it looks like a matter of design. The earth has another motion, that of rotation on its own axis which, as later consideration will show, is equally an essential for life. All this motion is of course controlled by the sun through gravitational forces.

But this is not the only function of the sun. The mass of the sun is the important factor in the control of the earth's motion. Actually, the mass of the sun is 300,000 times that of the earth. For the other major function a very high temperature is needed. It is actually something like 6,000° C. By virtue of this the sun pours forth an unceasing stream of radiation in all directions, that portion of it received by the earth, though only one 2,000-millionth part, being so essential for our life here. The intensity of this radiation at the mean solar distance of the earth, after correcting for that which is absorbed by the atmosphere, is known as the solar constant and has a value of about 1·95 calories per square centimetre per minute. This solar constant is actually subject to some variation from time to time, the changes apparently showing an eleven-year cycle following the same trends as the sun-spot frequency. The amount of the variation is reported to be some 1 per cent. either way from the mean, in all a range of 2 per cent. Other things being equal this variation would cause a change in effective earth temperature of $1\frac{1}{4}$° C. but actually other effects are largely compensative of this.[9] However, the important point for our immediate concern is not the variability but the constancy of the sun. What minor changes in intensity of radiation may have occurred in the past is not known ; but this much is known, that since life first appeared on the earth the sun has kept the earth's main temperature between 0° and 100° C. and since animal life appeared the maximum cannot have been over 70° C. as at this temperature, albumen, the chief constituent of protoplasm, coagulates and can no longer function. So far as we know astronomers do not expect a major change in this radiation for a long time to come. When we consider that this radiation is produced, according to modern theory, by the conversion of 3 to 4 million tons of matter per second, the constancy is amazing. This is considered so remarkable by Prof. Eve that he writes " if it had not happened (it) would be deemed impossible."[10] Surely this is an outstanding example of design.

In connection with this subject of the sun's radiation we should also briefly consider something of the manner of the earth's reception of it, particularly having in view two main purposes served thereby. First, we may continue the question of the maintenance of the earth's temperature. The thermal radiation from the sun, that is, the invisible radiation of longer wave-lengths, is largely lost to space by reflection and scattering at the outer atmosphere. It is different with the radiation of shorter wave-lengths. This includes both visible and ultra violet light, and is variously absorbed by the atmosphere and the surface of the earth itself. The importance of the atmosphere in this connection will be considered later, but it may suffice to mention here that in all about 63 per cent. of the radiation falling on the earth's atmosphere from the sun is absorbed and eventually serves to warm the earth. The effect of radiation on the temperature of the earth may be judged in approximate quantitative terms by supposing the earth's distance from the sun halved. This would increase the intensity of radiation fourfold and, other things being equal, would increase the absolute temperature at the earth's surface in the proportion of the fourth root of four. In other words, it would be raised something of the order of 100° C., that is, to a temperature impossible to life. Correspondingly, were the distance from the sun to the earth increased by one half, the temperature would be too low for anything like present conditions of life. It is true that different conditions in the atmosphere might entirely change these figures, but they serve to show how delicately balanced is the general system of emission and absorption of radiation as between the sun and the earth.

The second function of the sun's radiation is in connection with the growth of living plants. Though only about one-hundredth part of the solar energy reaching the earth is absorbed by plants and a further one-hundredth part only of this is used directly in this growth process, it is of supreme importance. The organic matter of living things is founded on the basic use of carbon dioxide by plants. This gas absorbed from the atmosphere reacts with water within the leaves to form carbohydrates such as sugar, at the same time liberating oxygen, which is returned to the air. The process only takes place in the presence of the green substance of plants (chlorophyll) and under the influence of light. The light is necessary to supply the energy required, and it must be of such wave-lengths that it is absorbed by the chlorophyll. Blue and red light such as predominate in light from the sky and sun respectively are readily absorbed. There is particularly strong absorption in the position of maximum energy of the spectrum. The energy of light stored by the plant during its growth is liberated again as heat when the plant substance is made to combine with oxygen, as, for example, during the burning of wood in a fire or the less spectacular, but equally true, burning of sugar within the human body. As vegetable life is necessary for the sustenance of animal life, light is in a very real sense at the basis of all physical life. No wonder then that the first recorded word of God was, "Let there be light."

Design in this matter of the relation between the earth and the sun becomes still more evident when we consider the conditions existing on the other planets of our system. Mercury, the nearest to the sun with an average distance of nearly 36 million miles, cannot be the abode of life because it always shows practically the same face to the sun. This face will therefore have a temperature far above the boiling point of water while the temperature of the other side probably approaches the absolute zero (— 273° C.). With a mass only one twenty-fifth that of the earth its atmosphere must be very scanty.

Venus, of much the same size as the earth and having a mean distance about 67,200,000 miles from the sun, is different. Apparently its period of rotation is about 68 hours, but its axis is nearly parallel to the plane of its orbit. This would be expected to result in extreme temperatures, the poles having in effect only one day and one night in the year. The heavy atmosphere is apparently mainly carbon dioxide and would have a blanketing effect. It has been estimated that the surface temperature is above the boiling point of water. Also there is little evidence of oxygen or water vapour so the possibilities of life are not very good.[11]

Mars is of course further from the sun than the earth and consequently tends to be decidedly colder. The cold at night is intensified by the long year (687 days) and by the rarity of the atmosphere, which in turn is consequent on the size of the planet. These and other considerations would tend to the belief that life on Mars, if any, must be localized and limited to peculiar primitive forms capable of withstanding the severe cold.[12]

The other planets are much further away from the sun and consequently have very low temperatures. On account of their large size they have dense atmospheres. Jupiter and Saturn both probably have ice coatings thousands of miles thick and atmospheres further thousands in depth. The atmospheres are probably largely hydrogen and helium together with ammonia and methane. Uranus and Neptune have been estimated to be at temperatures about $-200°$ C. They also have methane in their atmospheres. Obviously none of these is suited for life for two reasons at least. They are too far from the sun and hence too cold. They are too large and thus have retained too heavy atmospheres so that all oxygen has been combined with hydrogen or other elements, leaving none free in the atmosphere, which rather contains hydrogen compounds.

Briefly recapitulating in so far as this part of our subject is concerned, we can say that beneficent design is seen not only in the universe generally in that its properties allow of the formation and existence of a stable planetary system, but also in the particular properties of the solar system. It is seen in the quality, quantity, and constancy of the sun's radiation. It is seen in the mass of the earth and its distance from the sun. It is seen in the movement of the earth round the sun and in its own rotation both as to time and axial direction.

From our consideration of the solar system rather generally we turn to look at the earth itself in more detail. It will be desirable first to review the elements of which it is made, and with modern chemistry to aid us we are able to do this with remarkable completeness in a qualitative sense at least. Not only so, but lest any should suggest that in other worlds there may be other elements with vastly different properties than those that we find used in building our earth, we can definitely state that as far as any heavenly body that comes within the range of our telescopes is concerned no evidence can be found of the existence of such elements, nor are the properties of the elements found in any way different from those found on the earth under similar conditions. One element, helium, was discovered in the sun by means of the spectroscope before it was known on the earth. It is now of course well known on the earth and fits in exactly with the plan under which the rest of our elements have been designed. Designed is not inappropriate for the elements, because although for ordinary chemical purposes the elementary atoms are still the ultimate indivisible particles of matter, yet through a knowledge of radioactivity and modern physics it is known that these atoms are themselves complete structures which to some extent at least can be divided into their component parts. The number of different units used in the structure of the atoms is not yet known. For a time only two were generally recognised, the proton and the electron, but later other seemingly distinct fundamental entities as the neutron and positron have been discovered. The exact relations between all these and also between these and other very stable larger units cannot be defined, but this need not in any way affect our present general study of the chemical elements.

Without going into detail it may be said that atoms may be considered to be constructed with a central nucleus having a positive electrical charge, surrounded by a number of negatively charged particles (electrons) exactly balancing the central charge. It has been shown that, starting with hydrogen, the lightest known element, which has a central charge of one unit and one electron, all the known elements can be arranged in order of increasing nuclear charges, or atomic number as it is called, up to uranium, the heaviest known element. This has a central positive charge of 92 units and 92 surrounding electrons. With the exception of one or two gaps for which elements have not yet been discovered the whole series with atomic numbers from 1 to 92 is known, and no work has yet indicated the possibility of fractional charges so that the presumption is very strong for believing that all chemical elements in the universe are included in this scheme. When arranged in order the elements show remarkable gradations in properties, all falling in ordered series. It is quite possible that elements of higher atomic number than 92 exist, but these will still fit in with the general scheme and their properties are practically certain to be in accordance therewith. In any case they are of no practical importance for our present study, on account of their extreme rarity, if existent at all.

The relative amounts on the earth of the most abundant of the elements can be seen in the following table, which includes the atmosphere, the ocean, and the earth's surface to a depth of ten miles below sea level.[13] This is approximately representative of the materials ordinarily available for the support of life, and has been estimated from analyses made in many parts of the world.

| | Per cent. By Weight. | Atoms per 10,000. |
|---|---|---|
| Oxygen .. .. .. | 50·0 | 5,380 |
| Silicon .. .. .. | 25·7 | 1,570 |
| Aluminium .. .. | 7·3 | 470 |
| Iron .. .. .. | 4·2 | 130 |
| Calcium .. .. | 3·2 | 140 |
| Sodium .. .. | 2·4 | 170 |
| Potassium .. .. | 2·3 | 100 |
| Magnesium .. .. | 2·2 | 160 |
| Hydrogen .. .. | 0·95 | 1,630 |
| Titanium .. .. | 0·43 | 16 |
| Chlorine .. .. | 0·21 | 11 |
| Carbon .. .. | 0·19 | 29 |
| Phosphorus .. .. | 0·11 | 7 |
| Sulphur .. .. | 0·11 | 7 |
| Others .. .. | 0·70 | 180 |
| | 100·00 | 10,000 |

The second column is probably the most informative showing the relative numbers of atoms of each kind. Obviously oxygen is by far the most abundant. Oxygen is also very dominant in its chemical properties, being the most strongly electro-negative element except fluorine, which is not an abundant element and has numerous peculiar properties which unfit it to take a place such as that taken by oxygen. The next two most abundant elements are hydrogen and silicon, with each of which oxygen forms stable and very important compounds, respectively water and silica. Fundamentally we may say that the chemistry of the plutonic rocks is based on silica and its compounds, while that on the surface of the earth which more immediately concerns life is a chemistry of water.

In living organisms two other elements are always present besides oxygen and hydrogen, namely carbon and nitrogen. The need for these becomes clear if we bear in mind that the economy of a living organism requires that an enormous variety of chemical compounds must be possible from a comparatively small number of elements. This is in order that in a single organism with limited resources, the life may be able to adapt itself to very varying circumstances and manifest itself in an almost endless variety of ways. Of all the elements that we know, the most essential one beside oxygen and hydrogen is carbon. Out of the 90 or so known elements, and their general properties are well known, carbon has in an entirely outstanding way the property of forming stable compounds based on a framework of a large number of carbon atoms directly linked together in a great variety of chain and cyclical groupings. This unique property of carbon makes possible the fact that hundreds of thousands of distinct chemical compounds are known based on carbon, particularly combined with hydrogen and oxygen, and the number of such compounds that could be made is recognized to be practically without limit. The fourth element of this group, nitrogen, also possesses properties which enable it to enter in a variety of ways into these carbon compounds and to exert most important effects in modifying the properties of such compounds. Undoubtedly if a chemist were asked to select four elements which would allow of the formation of the greatest number of chemical compounds he would select just these four without any hesitation. To emphasize the point, we may mention that in the International Critical Tables, published in 1926, there are listed in the tables of important well-known chemicals well over 2,000 composed of carbon, hydrogen, and oxygen ; these three elements and no more, combined in various proportions. Whereas with sulphur, hydrogen, and oxygen, there are not fifteen known compounds and most of them quite unstable. Much the same is true if we consider phosphorus in the place of carbon and generally with the other elements. The possible number of combinations with hydrogen and oxygen is still less.

Two other elements do form a number of compounds with hydrogen of the same general type as the carbon compounds. These are silicon and boron. However, the number is incomparably less than with carbon, and in any case the nature of their oxides and oxygen compounds is such as would preclude them from filling the role of carbon in the general scheme of biochemistry.

Not only does carbon, with hydrogen and oxygen, form a great number of compounds, but they have the most amazing variety of properties. From these three elements, and no more, are formed such diverse materials as ether, glycerine, sugar, alcohol, acetic acid, digitalin, cellulose as in paper and cotton, Bakelite resin, linseed oil, acetone, carbolic acid, cellophane, formaldehyde, camphor, oil of wintergreen, and countless others ranging from fragrant perfumes to burning acids, volatile liquids to hard solids, regular articles of food to violent poisons. Carbon compounds are known with as many as sixty carbon atoms united together in one molecule, that is, the smallest unit of compound of a particular substance. Others occur with every degree of complexity down to the simplest such as formaldehyde, whose molecule has one carbon atom, two hydrogens and one oxygen. As to number, variety, and complexity, the carbon compounds are unique, so that organic chemistry, the chemistry of carbon, is practically a distinct sicence. In nature all these are ultimately built up from carbon dioxide and water.

A little further mention may be made of oxygen. Its strongly electro-negative character has been mentioned, and this has the important results that oxygen readily forms stable compounds with practically all elements, and in doing so large quantities of energy are liberated. On the first of these results depends the method of bringing many other elements into combination with the carbon compounds used in the structure of living matter; and on the second the convenient storage of energy to be liberated by oxidation. In connection with this last point it may also be mentioned here that hydrogen liberates by far the greatest proportional amount of energy of all the elements when it combines with oxygen. The heat of combustion of hydrogen is about 34,000 calories per gramme. Next in descending order of magnitude are boron at 13,000 and carbon at 8,000. These high values peculiarly fit carbon and hydrogen compounds to be reservoirs of energy, and seem to indicate definite design in the arrangement whereby energy is liberated by oxidation. Linked up with the same general topic are the stability of the oxides, water, and carbon dioxide, and their suitability to serve as the reservoirs of hydrogen and carbon respectively.

Further, not only can carbon form with these other elements an enormous variety of compounds, but it alone of all the known elements can produce materials having the physical properties needed for a living organism. The flexibility, toughness, and other characteristics needed in the body tissues to allow of movement and growth can only be obtained in structures built up of carbon compounds. It is thus evident that carbon, oxygen, hydrogen, and nitrogen as elements have been designed so that they might be capable of forming the material bodies of living beings. Other elements are also used, but these are dominant. Without these four, other elements form numerous useful compounds, but with negligible exceptions they are either rigid solids or structureless liquids or vapours. These are the only chemical elements that can fill this all-important place.

One more important point in the chemical view of things may be mentioned. There must be a means for bringing within the structure of the living organisms the materials needed from the outside world, and also a means of discarding used or otherwise unwanted materials. A fluid vehicle is obviously the only pessible type of means. When addition of material is needed to the inside of an automobile engine, for example, the thing is taken apart and the material added. It is apparent that no such method would do for a living body. The vehicle that is used in nature is, of course, water. We shall consider later some of the unique properties of water, but for the present just mention, in passing, its solvent action. Water is more nearly a universal solvent than any other known material. By virtue of this it is pre-eminently suited to make available the chemical resources of the world for the internal use of living organisms and to form the medium in which occur most of the chemical reactions connected with life. No other known liquid could serve instead.

Much more could be said along these lines, but enough has been said to show that physical life is only possible in an organism largely built up of carbon, hydrogen, oxygen, and nitrogen, and in a world where we have liquid water in sufficient quantity. In other words we see that organic life cannot be built up in anyway essentially different from that in which it is built up in this world. This confirms what has already been stated as to necessary temperature conditions. We can thus feel safe in agreeing with such a statement as that of Sir J. Arthur Thomson when he says, "There is no use in speculating over the presence of life on any planet where water is not present in liquid form. Man's imagination does not rise to picturing any kind of embodied life radically different from the protoplasmic plants and animals that we know."[14]

Very little attention has been given to the elements other than carbon, hydrogen, oxygen, and nitrogen, but in spite of their relatively secondary place in life they do have considerable importance in the world. It is only necessary to recall the wonderful varieties of materials that can be made to realize that the 90 odd different basic building units are indeed marvellously designed. As it seems now, the various atoms have all been made of identically the same fundamental entities in order to allow of their ready combination in different and yet strictly ordered ways. The proportions in which the various elements combine are regulated by a property called valence which is dependent on the relations of their basic structure. Because of this not only are all atoms of carbon and of oxygen, for example, identical, but when carbon and oxygen combine they do so in definite proportions. In this particular case there are three known possible proportions and they result in three specific compounds with their own distinct properties. So with all the elements in all their combinations. Through the combinations the endless variety of useful and beautiful materials result. Particular properties of a few of the chemical elements will be considered later, but enough has been said to show beneficent design in their general scheme and above all in the place taken by the four basic elements of living matter.

Having thus briefly reviewed the elements of which the earth is made up we look at something of the structure of the earth and the forms in which these elements occur. As is well known, matter exists in three states: solid, liquid, and gaseous; the transformations between them being dependent on temperature and pressure. This is in itself an evidence of design in that by change into the liquid or gaseous state the movement of matter is made possible in ways which could never be accomplished by solid matter, while solid matter is necessary for stability. For example, the moon is in a condition such that all the material thereof is permanently solid. It has neither liquid nor vapour. It is utterly dead. At the other extreme the sun is so hot that all or nearly all its matter is in the gaseous state. The existence of a living body is equally impossible. By contrast, the earth has all three states of matter represented; the gaseous in the atmosphere, the liquid in the ocean, and other waters or the hydrosphere, and the solid in the crust of the earth or the lithosphere. The centre of the earth may be liquid, but that is not our present concern. It will probably be convenient to follow this threefold division for this study and in keeping with the order as in Genesis, Chapter I, the atmosphere will be considered first, being also, perhaps, the simplest.

From the point of view of its mass as compared with the total mass of the earth, the atmosphere is really negligible, being somewhat less than one millionth part of the whole; however, this is not by any means a measure of its importance. The total gas in the atmosphere is equivalent to a layer about five miles thick at uniform normal pressure, or a mass of $5 \times 10^{15}$ tons. Its major constituents are nitrogen and oxygen, which are present in amounts of about 78 per cent. and 21 per cent. respectively by volume of dry air. Argon and other inert gases together amount to about 1 per cent. by volume, while carbon dioxide is only 0·03 per cent. These all are present in substantially constant amounts throughout the lower atmosphere. Moisture is also present in varying amounts as well as some minor other substances.

The total quantity of matter in the atmosphere is, as previously mentioned, dependent on the mass of the earth, a small mass being only able to hold a relatively small atmosphere by gravity. According to currently accepted views the atmosphere is now almost completely immune from loss to space, but how to explain its present constituents is still a problem. The proportions of oxygen and nitrogen are anomalous, a far smaller amount of oxygen being more usual. Theories have varied from those by which the primitive atmosphere was oxygen free but very rich in carbon dioxide to those postulating an originally much greater oxygen content. Without deciding in favour of any theory we notice the difficulty of explaining the atmosphere on the basis of chance as it emphasizes the element of design, as will be the more apparent from a consideration of the part played by the different gases in the economy of nature.

Nitrogen, the major constituent of the air, is an indispensable element in the formation of protein without which no living creature exists. For the original supply of this we must look to the atmosphere except for possible minor amounts from volcanic materials and certain mineral springs. In accordance with the general principle previously stated we find in nature a vast circulation known as the nitrogen cycle.[15] The distribution of nitrogen in the world has been estimated as in the following table, the figures being in millions of tons:

| | Millions of Tons of Nitrogen. |
|---|---|
| Coal and peat .. .. .. .. | 100,000 |
| Soil .. .. .. .. .. | 40,000 |
| Vegetation (mainly forests) .. .. | 592 |
| Animals (including man) .. .. | 11 |

The amount in the atmosphere is much greater than in any of the preceding forms, being $4 \times 10^{15}$ tons. How this is brought into use in these other forms will next be discussed.

To ordinary chemical reaction elemental nitrogen is comparatively inert and cannot be used by higher plants or animals, but a comparatively small quantity is combined with oxygen by electrical discharges in the atmosphere and brought down to the earth as nitric acid with rain. Incidentally this combination of oxygen and nitrogen absorbs a large proportion of energy. If it liberated energy, that is, if it were exothermic as almost all combinations with oxygen are, the first thunderstorm would deluge the world in nitric acid and bring an end to organic life. However, actually the amount of combined nitrogen so brought down is but small, estimated at one pound per acre per year. Other nitrogen in the air combined as ammonia probably arises from decomposing organic matter in the earth and is similarly brought back by the rain. It is perhaps four pounds per acre per year. This would be insufficient for anything like the present plant growth, but the needed amount is made up by living organisms which have the power of fixing the nitrogen of the air and transforming it in the soil into compounds useful for higher plants. These organisms are chiefly bacteria, but also include some fungi and algæ. The bacteria are of two main types, non-symbiotic, particularly the Azotobacter group, and the symbiotic, particularly those that co-operate with legumes, fixing nitrogen in their roots. These last will fix on an average about 50 to 60 pounds of nitrogen per acre of legumes per year, while the other types of living organism account for some 10 to 20 pounds per acre. Of the combined nitrogen thus brought into the soil part is lost to the ocean in drainage, part is decomposed by other bacteria to free nitrogen again and part is used in plant growth. This last may be used by animals before returning to the soil or directly returned. In either case it enters the cycle again. The eventual loss from the soil is either as free nitrogen or in drainage.

This net loss is made up by the processes just described. Artificial means now at man's disposal allow of transforming the atmospheric nitrogen into chemical fertilizers for addition to the soil so entering into the great cycle whereby the essential nitrogen is drawn from the inexhaustible reservoir of the air, used by all living things, and ultimately returned to the atmosphere. Nitrogen in the air was evidently in the design for the world.

Equally interesting and vital is the cycle of oxygen linked with carbon dioxide. Part of this has already been mentioned in connection with radiation, but may be referred to again. However, before doing so further attention should be given to the existence of free oxygen in the air.

Oxygen is a very different element from nitrogen in its chemical properties. It readily combines with nearly all other elements to form stable compounds. This is evidenced by the fact that the known part of the earth's crust contains about 50 per cent. by weight of combined oxygen. The contrast with nitrogen is worth further emphasis. The total amount of this latter element in the known material of the earth is smaller than that of any included in the table given earlier, being actually about 0·03 per cent. How important it is then that this relatively small amount should be preserved in a state at once available all over the surface of the earth! That this is so is dependent on the fact that nitrogen does not readily form stable compounds which would have bound it in the earth's crust. Oxygen, on the other hand, is present to a very large extent, but still provision has been made that a sufficient portion of the whole should be uncombined and present all over the globe. This is remarkable when we consider that of the vast amount of oxygen present in the earth's crust about 99·98 per cent. is combined in the various minerals and water, and so is not available for respiration. Upon the stable existence of the remaining five-hundredth part in the free gaseous state all animal life depends. If, for example, the hydrogen content of the crust had been a fraction of 1 per cent. of its amount larger than it is, it would have sufficed to combine with all this oxygen in the form of water. At least one modern authority recognizes this fact, that the oxygen of our atmosphere is "The excesss of that element that remained unused after all the possible oxidations had been effected".[16] In the case of the planets Jupiter, Saturn, Uranus, and Neptune, there actually is a large excess of hydrogen and its compounds in the atmosphere, and of course no free oxygen, as we noticed before.

The oxygen cycle on the earth is maintained by the liberation of free oxygen from carbon dioxide by vegetation and the consumption of free oxygen by animals, various combustion processes and the oxidation of weathering rocks. The quantities involved in these processes are of general interest. Thus it has been estimated that an average man exhales about three pounds of carbon dioxide per day and that three trees each 200 feet high and weighing 24 tons are needed to use up this and restore the oxygen consumed. In a recent paper before the Meteorological Society it was estimated that some 4,300 million tons of carbon dioxide are added to the atmosphere annually by combustion of fuels, and that between 1900 and 1936 the carbon dioxide content of the atmosphere has increased by 6 per cent. of its amount.[17] This change is not detectable from data available at present. Similarly although there is considerable opinion that the oxygen content of the atmosphere is decreasing, analytical means have not been sufficient to prove the case. There are various minor changes in both the oxygen and carbon dioxide contents of air from time to time and place to place but definite trends are difficult to establish. Possibly the carbon dioxide was much higher in early geological times and was reduced to its present levels by the heavy vegetation and by combination in mineral carbonates. At least it is certain that since modern animals appeared, the oxygen content of the air has not seriously changed and there is a well-planned mechanism to maintain a suitable supply.

Carbon dioxide deserves further consideration in view of its importance in a number of ways. Its solubility in water is one outstanding property. We have already noticed how it pervades the surface of the earth by its universal presence in the atmosphere. This pervasiveness is greatly extended by its solubility in water so that not only is carbon dioxide present in all the atmosphere but it is also in practically all waters. Its solubility coefficient in water is intermediate in magnitude. It is about 35 times as great as that of oxygen but only one-fortieth of that for sulphur dioxide and still less than that for ammonia. This is not unimportant because with gases the amount dissolved in a liquid varies with the concentration of the particular gas in equilibrium. The relatively high coefficient allows appreciable carbon dioxide to dissolve in waters even though the concentration in the atmosphere is only 0·03 per cent. On the other hand, its coefficient is not too high, as for ammonia, or the atmosphere would be stripped of practically all the carbon dioxide. But with an intermediate solubility it can under different conditions be absorbed or evolved from aqueous media without undue concentrations or too severe conditions being necessary. This is highly important for physiological processes. The three pounds, or so, that an average man produces per day must be got rid of. This can be done because carbon dioxide is readily dissolved in the blood and then readily given off again in the lungs. For this process alone it is evident that it is at least very advantageous that carbon dioxide is a gas and that it has a moderate solubility in water.

The nature of the solution formed when carbon dioxide dissolves in water is also of great interest. As is well known, this solution is slightly acidic, carbonic acid. This acidic character greatly aids the dissolving power of water for many types of rock minerals. This is well illustrated by the so-called temporary hardness of many natural waters. In these, calcium carbonate is dissolved as the acid- or bi-carbonate by means of dissolved carbon dioxide. When such water is boiled the carbon dioxide is driven off to the atmosphere and the calcium carbonate can no longer he held in solution, but precipitates. Clearly such action is of major importance in the weathering of rocks. Though it has a comparatively powerful dissolving action in geological terms, yet carbonic acid is chemically speaking a weak acid. This is also of significance in its physiological action, particularly in what is called its buffer action.

This buffer action is the power possessed by solutions of carbonic acid and its salts to reduce changes in the acidity or alkalinity of such solutions when subject to changes in concentration or additions of other chemicals. An example as given by Professor L. J. Henderson will illustrate this.[18] We start with a solution of 1 kilogram of carbon dioxide in 100 kilograms of water. This has a mild acidity which we can represent by the factor 1000, this being the number of times the hydrogen ion concentration is greater than that of pure water. Equivalent acidity would be produced by dissolving about one-third of a gram of hydrochloric acid in the same quantity of water. If now caustic soda is added to the carbonic acid solution, even as much as 700 grams will only just bring the acidity to a little less than that of pure water. Adding the soda to the hydrochloric acid half a gram would have more effect, and correspondingly in pure water even a two-hundredth part of a gram would have a greater effect. If the carbonic acid solution is in equilibrium with the gas its buffer action is still stronger. Now many chemical reactions in solution, particularly those of the general type that occur in the processes of metabolism, are markedly affected or even regulated by the acidity or alkalinity of the solution in which they take place. This controlling action of carbon dioxide and its salts allows the body fluids to take up considerable quantities of different compounds, particularly such as acidic end-products of food stuffs, without any great change in their acidity. About the only other volatile acid that has a similar strength to carbonic acid is hydrogen sulphide. This, however, is altogether too unstable to function in this way. Carbon dioxide shares this important power with no other substance.

One other chemical feature about the atmosphere worth mentioning is the absence in it of any poisonous substance. As we are at present constituted, if the carbon dioxide content were increased to 10 per cent., animal life would be seriously upset, while at 25 per cent. death would ensue. But it is not so. In fact it has been said that air is the only substance entirely non-poisonous in that it is the only one of which unlimited amounts cause no harm.

The atmosphere serves other purposes also that evidence its design. One of these is its blanketing effect. In a general way it is clear that the atmosphere moderates the heat of the day and the cold of the night. As is well known, the temperature of the atmosphere decreases with increasing altitude fairly regularly, for about 6 miles in temperate latitudes, after which a constant temperature layer extending a further 12 or more miles is reached. The temperature of this is about — 50° C. All vertical convection takes place within the lower atmosphere and this portion is largely responsible for the temperature regulating effects.

Actually the absorption of radiation by the air is mainly due to its moisture content and in lesser degrees to ozone, dust, and carbon dioxide. However, although these substances absorb effectively in a region of the sun's radiation where the energy transmitted is appreciable, they are transparent over a very considerable region, corresponding to roughly one half of the total energy. Were they absorbent to all, the temperature at the earth's surface would be much lower and darkness would reign. Further, when the transmitted radiation reaches the earth's surface it is absorbed and the balancing energy leaving the earth as radiation is of much greater average wavelength. This is to a far greater degree absorbed by the water vapour, etc., so producing a very marked greenhouse effect. These absorption phenomena are at the basis of the vertical temperature gradient previously mentioned, and this in turn is the main ultimate cause of wind, whose effects on rainfall distribution and temperature are patent to all, and clearly necessary for any widespread distribution of life. The limit to this temperature gradient at the boundary of the stratosphere is fixed where the air reaches a temperature such that its absorption and emission of radiation are equal. This again links up with climate and weather.

Another interesting feature in connection with the sun's radiation is the effect of ozone. In the upper air some 15 miles high there is a significant amount of this element. It is formed from the ordinary oxygen by absorption of certain parts of the sun's radiation and it is sufficient to remove from the radiation received on the earth practically all the ultra violet with wavelength below 2,885 Ångström units. The stability of this ozone depends on the dry low temperature conditions in the stratosphere, and it has been estimated on the average to amount in all to the equivalent of something like one-eighth of an inch at normal pressure. It is said that were this amount considerably greater there would be such a reduction in ultra violet light on the earth that bacteria would multiply to a most dangerous degree for higher life. On the other hand, were it much less, then this radiation would be positively harmful to human beings. We saw before that the total oxygen of the air is an almost infinitesimal proportion of the whole, and now we find that our present organised life is dependent on a further tiny fraction of this existing in a particular modification. It scarcely looks like chance.

Before leaving this part of our subject it may be worth mentioning the ability of the atmosphere to transmit sound. This depends mainly upon its elasticity. Though perhaps not so essential to life as some other properties it is not beyond the range of beneficient design for man's fuller life.

We now turn to a brief review of the hydrosphere, the part of the earth's surface existing in the liquid state. By far the greater part of this is the ocean, which covers some five-eighths of the whole surface of the earth and has been estimated to contain well over 300 million cubic miles of water, each cubic mile containing some 4,000,000,000 tons. Dissolved in the ocean there are many different salts which need not occupy us at present except to notice that if separated they would occupy a solid mass over 4,800,000 cubic miles. In comparison with the ocean, the quantity of water in rivers and lakes is almost negligible, but its importance is not in this proportion by any means.

That water is necessary to life is well known and is emphasized by the large proportion of combined water in animals and plants, for example, fish contain about 80 per cent.; the human body, 70 per cent.; ordinary land plants, 50 to 75 per cent.; and aquatic plants, 95 to 99 per cent. Many rocks also contain very considerable amounts of combined water; in fact, it has been estimated that three quarters of the surface material on the earth's crust is water. Of course, not all this is properly part of the hydrosphere, but a mention of it may not be out of place at this point. It will also be necessary for us to consider in this general connection the behaviour of water in the atmosphere. These introductory remarks about water will serve to remind us of its unique place, as has been recognised from antiquity, and by way of showing in more detail some of its chief properties we will outline the vast movement of nature known as the water cycle.

The general recognition of this goes back at least as far as the writing of the book of Ecclesiastes where we read that "all the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again."[19] Perhaps the writer did not at the time know much of the many and varied factors that come into play in the circulation so briefly described, but we can to-day set out sufficient of these at least to show the hand of the Great Designer at work.

For the immediate requirements of life on land the water of the ocean must undergo a twofold change. It must be purified, that is, separated from its dissolved salts, and it must be distributed over the land surface. The first step to accomplish these ends is evaporation, which has been estimated to be about 7·5 feet per year at the equator. Heat from the sun, either directly or indirectly, supplies the energy needed to bring about this evaporation. The amount of the evaporation is dependent on a variety of factors. One of the most obvious is the area of water exposed. Suppose, for example, that the relative areas of ocean and land on the earth's surface had been reversed, then the average rainfall would only have been about one-third of what it is. There may be more than poetry in the words of the ancient prophet, "Who hath measured the waters . . . and comprehended the dust of the earth in a measure."[20] Another important factor in connection with this evaporation is the removal of the water vapour from the air immediately above the ocean. This is brought about partly by diffusion, but the process is greatly accelerated by the wind (basically dependent on radiation and absorption as we have just seen) and by the lightness of water vapour causing it to rise in air. The lightness or low specific gravity of water vapour (about 62 per cent. of air) is quite remarkable. Liquid water is relatively heavy, yet water vapour is lighter than any other gas or vapour with the exception of a very few such as hydrogen, helium, ammonia and methane, and some quite uncommon vapours at high temperatures.

This evaporation of course is the method whereby the water is purified, and depends on the simple fact that water is volatile while the salts of the ocean are not. This is a simple fact, but why it should be so other than by design is not so simple. Mercury, for instance, one of the few other naturally occurring liquids beside water, although at ordinary temperatures it is considerably further from its freezing point than water, has an entirely negligible volatility as compared with water. In fact water is almost the only naturally occurring substance which is found on the earth in the three forms, solid, liquid, and vapour. At the moment the important feature is that the liquid has under ordinary conditions on the earth a relatively high vapour pressure or volatility. Even from the solid appreciable evaporation also takes place.

The water vapour rising by virtue of its low density and carried by winds and convection currents reaches upper levels where the lower temperature causes condensation. This has been previously explained, but it may be worth mentioning that it is by no means obvious that upper levels should be colder. In any of our buildings the air is warmer at the ceiling and in the upper stratosphere there is a wide zone where the temperature rises with increasing altitude. The fact that we may have what we call a scientific explanation as to why the temperature of the troposphere decreases with altitude does not detract from the reasonableness of the belief that this is a designed feature in view of bringing about among other benefits the condensation of water vapour. The quantity of water condensed by any given drop in temperature is dependent on the change in vapour pressure or vaporization. At the temperatures prevailing, the change in vapour pressure of water is remarkably high, thus aiding the processes resulting in dew and rain.

Condensation of water vapour also depends on the presence in the air of a multitude of dust particles to serve as nuclei for the formation of drops of water or crystals of ice, otherwise precipitation would occur in the form of catastrophic cloudbursts.

Distributed by wind as we have seen, the water is brought to the different parts of the earth's surface as rain and snow. Lower temperatures in the upper air tend to bring heavier precipitation on mountains from whence the water drains to lower levels with obvious benefit. The cold of high altitudes whereby the water is stored as snow to be gradually melted and flow down is also connected with the same general group of phenomena. A small fraction of the total precipitation is fixed in the earth, but for the most part it either runs off, percolates through the earth and by springs and rivers reaches the sea again, or is reevaporated either directly or after use in living organisms.

A few data, estimates of Sir John Murray and others, may be of interest to show the magnitude of the circulation involved. The total average annual rainfall on all land is 29,347 cubic miles of water, of which 6,524 cubic miles drain off to the sea. The area of land so drained is 40 million square miles and the dissolved matter taken to the sea by this drainage is some 2,500 million tons per year, equivalent to the lowering of the land surface by one foot in 30,000 years. That this quantity of material is dissolved is confirmation of the remarkable solvent powers of water particularly aided, in the case of mineral matter, by carbon dioxide. Of this, rain has been reported to contain 0·0013 per cent., and more is added to streams from decaying organic matter and other sources. Of the total solids in the water of the chief rivers of Europe about 60 per cent. is said to be calcium bicarbonate. The total quantity of sodium chloride carried to the ocean annually is about 160 million tons at the present time.[13]

In connection with this dissolving action of water it should be noted that it is done without chemical action. Other chemicals we know of would, in equal quantities, dissolve more minerals, but they would be used up in the process so that the action could not be continuous. With water, however, the action is one of ordinary solution and the water is completely recoverable by evaporation to be used over again. The same is true, to a large extent at least, in the case of carbon dioxide. Here, although there is definite chemical action, yet by virtue of its volatility much of the carbon dioxide is liberated to the atmosphere again to be re-absorbed in rain.

The ocean has other valuable functions besides serving as a source of water. One of these of considerable importance is temperature regulation. This is of particular interest because it depends for its effectiveness on a number of remarkable properties of water.

The ocean shows constancy of temperature to a great degree. Its surface in open waters never goes above 15° C. and in the great depths the range is from — 2° near the poles to 2° C. at the tropics. Needless to say, this constancy is of great importance in reducing temperature changes on land surfaces. It is maintained in the first place by the high heat capacity of water. With the single exception of ammonia, which at normal temperatures has a heat capacity about 10 per cent. greater, water has the highest specific heat of any known substance. This means that a comparatively large quantity of heat is required to change the temperature of water, perhaps four times the average required for other substances.

As heat is added, however, the temperature does rise to some extent, but this rise is much reduced, in conditions prevailing in nature, by evaporation. This of course absorbs heat as in the case of all substances. In passing it may be noted that this universal phenomenom of absorption of heat when passing from the solid to the liquid or the liquid to the vapour state may in itself be taken as an evidence of design in the stability it confers on the different states of matter as well as in other ways. With water, however, the general phenomenon becomes something unique, because water has an unusually high vapour pressure at temperatures proportionately near its freezing point, because it has an usually high rate of increase of vapour pressure so that the heat absorption rapidly increases as temperature rises, and particularly, because it has, by a very considerable margin, the highest heat of evaporation of any known substance. It is easy to see how these properties, most certainly unique in their combination, reduce the rise in temperature that would otherwise occur when water is subject to heat from the sun or other sources. Of lesser importance but still an aid is water's degree of transparency to the sun's radiation whereby all the heat is not concentrated in the surface.

When water is subjected to loss of heat similar phenomena come into play. Clearly the high specific heat and the falling vapour pressure will tend to retard the cooling, but eventually the freezing point may be reached. Now water has a remarkably high freezing point, perhaps 100° C. higher than the average of other chemical substances of comparable structure. This fact is particularly important for living organisms because, as the temperature falls, the chemical processes on which life depends become more and more sluggish. If water froze at the same temperature as hydrogen sulphide, for example (— 83° C.), it is almost certain that processes of life would be entirely suspended even if death did not ensue before any actual freezing took place. At least the effects on aquatic life would be most serious. When the freezing point is reached, further loss of heat does not lower the temperature, but the change of state to the solid, ice, occurs. Again water is remarkable. It has the highest latent heat of fusion of any substance except ammonia and a few alkali salts.

The high heat capacity of the ocean is also important in the formation and maintenance of the ocean currents and in the origination of winds. The relatively high heat conductivity of water as compared with other non-metallic liquids also aids in equalizing temperatures. Altogether a most remarkable group of phenomena combine to make the vast body of water of the ocean an effective temperature regulator.

The ocean also has a regulatory action in connection with the carbon dioxide in the air. The quantity of carbon dioxide dissolved in the ocean is over twenty times as much as in the atmosphere. There is a circulation between the two, the colder parts of the sea removing some from the atmosphere and the warmer parts restoring some. Perhaps there is a net withdrawal from the air in this process, linked with the dissolution of calcium carbonate, but this is not at all marked and certainly the ocean does help to maintain a suitable carbon dioxide concentration in the air.

The ocean and other waters also dissolve oxygen and nitrogen from the air. The former is of importance for the oxidation of dead organic matter and the maintenance of life of marine organisms. In this connection it is interesting to notice that although the air contains only one-fourth as much oxygen as nitrogen, a given quantity of water will dissolve from the air about one-half as much oxygen as nitrogen. In other words, the relative solubilities of these gases in waters is such as is to the advantage of living organisms. The solubility of carbon dioxide was previously discussed and it may further be pointed out that if oxygen had a solubility in water as great as that of carbon dioxide depletion of the oxygen content of the air would take place to a serious extent. Actually, the amount of oxygen dissolved in the ocean is about one and one-half per cent. of the oxygen in the atmosphere.

Other qualities of the ocean of importance to marine life are its salinity and alkalinity. There are slight variations in salinity from place to place, but the relative concentrations of the different salts are remarkably constant. Chlorine, for example, is always very close to 55 per cent. of all the dissolved substances, even though the total concentration of salts varies from about 3 per cent. to about 4 per cent. It appears that physiologically the relative quantities of the various salts in sea water is quite important. It has been shown that single salts, and various other combinations of salts are definitely toxic to fish, but that sea water has such amounts of chlorides, sulphates, and carbonates of sodium, potassium, calcium, and magnesium and other constituents as form a balanced solution most suited for marine life. Of equal importance is the faint alkalinity of the ocean, which is variable only to a very small degree. This is important, because changes would have great effects on processes of metabolism. While it may be argued with some reason that the living organisms could have been adapted to other types of solution, this much is apparent, that the solution we find in the sea is very suitable and that its relative invariance is certainly essential.

Another unique property of water that is of great importance in natural waters other than the ocean is its anomalous behaviour on cooling. As water is cooled it first contracts in volume and so becomes denser as do all other substances. The result of this is that normally the coldest part of a body of water is at the bottom. However, 4° C. before reaching the freezing point, water ceases to contract and starts to expand again on further cooling. No other known substance behaves in this way. Below 4° therefore the coldest water is at the surface, and when freezing takes place it starts on the surface. As the ice formed is less dense than water it remains on the surface, forming a protective covering that reduces the rate of further cooling. If these changes in density did not occur freezing would start at the bottom of lakes and streams and would proceed until in the winter in many parts of the world the whole body of fresh water would be frozen solid. In many parts the heat of the summer would be insufficient to completely thaw the ice so that serious restrictions to life would result.

Still another property in which water is unusual is its high surface tension. It has a considerably higher surface tension than any other common liquid except mercury. This is of value in that water will rise by surface tension about 4 or 5 feet in ordinary soils as compared with 2 or 3 feet that other liquids would rise. Mercury, even though it has a higher surface tension, would not rise in this medium but would be depressed. It is highly probable that the surface tension of water is also of benefit in this way in the movement of water in living organisms. It certainly is of importance in adsorption. According to Gibbs' rule, if the solution of a substance in a liquid has a lower surface tension than the pure liquid then the dissolved substance tends to accumulate at the surface of the liquid. The reverse is true if the substance dissolved increases the surface tension. By virtue of its high surface tension water is peculiarly fitted to show this effect, and the resulting adsorptions on the greatly extended surfaces in living matter are of no small importance.

Once again, water is outstanding in its dielectric constant ; it is amongst the highest known for liquids. It would be beyond the scope of this paper to go into this matter in detail, but it may suffice to say that the dielectric constant is a measure of a property of a medium on which depends the force of electrostatic attraction through the medium. A high dielectric constant reduces the force of attraction, and in the case of a solvent it thereby increases the ionisation of an electrolyte dissolved therein. An electrolyte is a substance which has the power of conducting an electric current when dissolved, and this is done by its ionisation. This latter phenomenon is a more or less complete dissociation of the dissolved substance into two or more types of particle called ions, in the solution. These ions are of two kinds, having respectively positive and negative electrical charges. Upon them depend all electrical phenomenon in solutions and many processes, particularly connected with colloids in living organisms, as has been demonstrated by J. Loeb and many other physiologists. Water is again seen to have properties peculiarly fitted for the all-important part it has to play.

Perhaps one or two other properties of water more in the chemical line will be all that space will allow of mentioning at present. It has been shown that a great many chemical reactions will not take place at all except in the presence of a trace of water. For example, when dried with the powerful chemical agents now available, hydrogen and oxygen gases will not combine even when heated to 1000° C. Similarly sulphur, carbon, or phosphorus will not burn in perfectly dry oxygen. A great many other instances of this are known so that water is necessary not only when it is obviously used as in biochemical processes but also when it is present in such minute amounts as to be ordinarily unnoticed.

Water enters more directly into a class of chemical reactions known as hydrolysis. These are of major importance in biology and can be so used because they take place with very slight energy changes and because they are reversible.

Before leaving the subject of water it should also be pointed out that the same properties of water that aid in keeping the ocean temperature comparatively uniform are also operative to the same end in animals, except that the properties connected with freezing do not function. Thus water is fitted to be a major constituent of animal bodies in order that temperature changes may be kept at a minimum and particularly that exertion may not cause too high a rise. Temperature needs to be relatively constant in animals because the rates of the chemical processes of metabolism are dependent upon it.

Evidently water, the fundamental constituent of the hydrosphere, has been designed to fill a place that no other known substance could occupy.

We now turn to the last of the three divisions under which we are considering the earth, the lithosphere. In the first place, we may ask why there should be this solid matter at all. It is fairly evident that active life is impossible in an entirely gaseous region, and that severe limitations would be imposed in an entirely liquid region. This is confirmed in that very few creatures could live in a shoreless ocean. It is also more obvious that civilized human life is dependent in many ways on the existence of the solid crust of the earth. The mention of the appearing of dry land even before fishes in the account of Genesis I is of interest in this connection.

The solid state of the earth's crust is dependent upon its relatively low temperature, and it may be presumed that cooling has taken place allowing this solidification. The rate of cooling and the time elapsed since the solid crust formed have been the subjects of considerable study and speculation. It appears at present that radioactive matter provides a continuous supply of heat that is of no little importance in this connection. Thus if the total quantity of radioactive matter had been much greater, cooling would have stopped altogether, at least until all this matter had been spent. Also if the radioactive matter actually present had not been largely concentrated in the upper layers of the earth's surface as it is, then the depth of solid crust would have been much less with perhaps very serious consequences to living beings.[21]

We have previously mentioned the importance of the relative land and water surfaces of the earth, which is of course dependent to a large extent on the irregularities in the solid crust. These irregularities are important in other ways also. Of the dry land about 90 per cent. has an elevation less than 6,000 feet above sea level. This is all quite habitable as far as elevation is concerned. Further, of this same dry land about two-thirds is comparatively level, either plains or plateaus, obviously to the advantage of man. When it is considered that from the highest mountain peak to the lowest sea depth is only a vertical distance of twelve miles compared with the earth's diameter of nearly 8,000 miles design can be seen in what might otherwise look like the merest chance. On a globe reduced to the size of an orange a mountain range would be no more than a hair's breadth, only a surface roughness ; but if the surface had been a little smoother or a little rougher what a difference it would have made to the earth as habitable ! Other effects of land masses on climate and weather we pass over.

However, the dry land is more than so much solid matter of a given shape. It is not only a place on which man and animals can move about. It is the essential support of vegetation. Although it has been said that plant growth is, except for about

2 to 5 per cent. of its substance, the product of air, moisture and sunshine, it must be admitted that the 95 to 98 per cent. cannot exist without the 2 to 5 per cent. In other words, plants must have soil.

Soil must have in the first place a physical structure allowing the penetration of moisture and air to a sufficient depth for root development. This structure is due to weathering of rocks, particularly by the changes of temperature and the action of water. Climatic conditions, the expansion of water on freezing, the dissolving power of water, the effects of carbon dioxide and oxygen and other factors previously discussed all play their part in this work of soil formation.

From the chemical point of view it is also necessary that soils have neither too great an acidity nor too great an alkalinity. The buffer action of carbon dioxide plays a part in this. Besides all these there must be an available supply of the necessary nutrient elements. We have already spoken of the main four elements used in organic compounds, but many others are recognised as necessary to life. The more common ones are phosphorus, sulphur, chlorine, calcium, magnesium, sodium, potassium, and iron. Minor constituents also believed necessary in very small amounts include copper, boron, silicon, manganese, zinc, iodine, and fluorine; while many other elements seem necessary for certain species at least. For example, "bush sickness," a disease of sheep prevalent in New Zealand, was found to be due in part at least to the absence of cobalt in the feed, which in turn was due to a lack of this element in the soil. Only a very small quantity is needed, in fact too much would be poisonous. To what extent life would be possible without these minor elements is beyond present capabilities. Certainly many of them play a very important part and soil generally throughout the world is so constituted that as regards the soluble matter that directly affects plants a multitude of necessary elements is present in suitable, generally very small, amounts. Even soil shows beneficent design.

Space fails for other than brief mention of the main useful properties of the various minerals of the earth and the products that man has been able to contrive from them for his convenience and comfort. Nearly all the known elements have their uses to-day even though not essential, and doubtless new properties leading to new uses will be found in the future. But this is surely enough.

We have viewed the universe in its basic structure, the solar system with its component parts, the particular relations of the sun and the earth. We have counted the elements of which the earth is made and seen their different proportions. We have thought of radiation, of the atmosphere, of the ocean and streams flowing into it, of the solid crust of the earth. We have studied the chemical properties of oxygen, nitrogen, carbon, and hydrogen. We have found carbon dioxide and water, particularly the latter, to be well-nigh miraculous substances. We have dealt with traces of ozone in the stratosphere and with minute proportions of radioactive elements in the lithosphere. Looking back, we are not surprised that L. J. Henderson says " There is, in truth, not one chance in countless millions of millions that the many unique properties of carbon, hydrogen, and oxygen, and especially of their stable compounds water and carbonic acid, . . . should simultaneously occur in the three elements otherwise than through the operation of a natural law ".[18] We have gone further in our range. We go further in our conclusion. We do not stop at natural law. We recognize beneficent design.

" Lo, these are parts of His ways: but how little a portion is heard of Him ! "

Numbers in the text refer to the list below. Where direct references are not given, as in cases 9, 13, 14, 16, 18 and 21, the sources of information are named. In other cases support can be found in any modern text-books on Astronomy, Chemistry, and Physics for the statements made.


[1] Proverbs viii, 31; Isaiah xlv, 18.
[2] Genesis i, 30–31.
[3] Job xxxviii, 41.
[4] Job xxxix, 13.
[5] Matthew x, 29.
[6] Genesis i, 28.
[7] Matthew x, 31.
[8] Genesis iii, 17; Romans viii, 19–23.
[9] " Physics of the Air," p. 29, Humphreys (1929).
[10] " Nature," 16th May, 1936.
[11] " Nature," 10th December, 1938, H. Spencer Jones.
[12] " Transactions," Vol. 44, E. W. Maunder (1912).
[13] " Data of Geochemistry," F. W. Clark (1920).
[14] " Biology for Everyman," p. 915.
[15] " Fixed Nitrogen," chap. II, H. Curtis (1932).
[16] " Americana," article on Atmosphere (1937).
[17] " Nature," 26th March, 1938.
[18] " Fitness of the Environment," L. J. Henderson (1924).
[19] Ecclesiastes i, 7.
[20] Isaiah xl, 12.
[21] " Encyclopædia Britannica," article on Earth (1937).

## Discussion.

Rev. Arthur W. Payne, expressing his gratitude for the Gunning Prize Paper, said its devout and scriptural spirit would have been one that would have delighted the recently Home-called Mr. Sidney Collett. The reading of it and the summary of much of its contents was most admirable, and he thanked Dr. Palmer sincerely.

The general tone reminded him of probably the oldest book in the Bible, that of Job. It was well that the British Empire was represented in the Victoria Institute through this fine message of Dr. Sutherland, of British Columbia. It was indeed a day when knowledge was increasing in the earth.

The references to Beauty in inanimate Nature reminded one of the expression in the Greek for a " good " heart, which is " Kalos." " I am the Good Shepherd " is also the " Beautiful Shepherd." One thought of the colours of the High Priest's garments and of the Tabernacle structure, and the Stones of the Heavenly Jerusalem, and the multi-coloured stars in the night sky—indicative of Jehovah's love of beauty.

## Written Communications.

Rev. Principal Curr wrote : Dr. Sutherland makes an excellent point when he observes that the overwhelming balance of the evidence furnished by the marvellous correspondence which exists between the maintenance and welfare of the human race and the general structure and behaviour of inanimate nature, is of such a kind that we must postulate a beneficent and intelligent origin to explain it. He does not argue that there are no difficulties associated with that phase of the argument from design, which he has discussed with such thoughtfulness and thoroughness. He frankly recognises that hailstorms, and tornadoes, and earthquakes can work awful havoc amongst the children of men, and yet he emphasises the great truth that these are exceptional. They only attract so much attention because these things happen so infrequently. Over against them it is necessary to set the one consideration that the world's population is steadily increasing. If conditions were intolerable, that would be most unlikely to happen. There is ample evidence of the kind which the paper adduces in such abundance to undergird the unfailing optimism of the Bible, which finds such adequate expression in the famous words, " And God saw everything that He had made, and behold, it was very good " (Genesis i, 31). To use the language of commerce, the credit balance is still large enough to overshadow all that points in the opposite direction. The records of crimes and disasters to which the newspapers give such prominence are, after all has been said, so exceptional as to be quite abnormal. The ordinary march of man's affairs is so widespread that it is taken for granted. In the same way the occasional deviations of inanimate nature from its path seem matters of great magnitude, which they often are, but that is only because they are so unusual.

On the other hand, it is always well to bear in mind, as the paper implies, that, to the understanding which has been enlightened by celestial wisdom, inanimate nature wears a very different appearance from what it does to the savage who is the prey of superstitions of the most debasing type. To him the inanimate world is the abode of a multitude of malignant spirits whose one aim and object is to work him harm. Life is thus resolved into a long-drawn struggle with these supernatural forces and factors lurking in every bush and stone and stream. It is not co-operation with an immeasurably large and powerful as well as immeasurably beneficent system, as for the Christian, but endless wrestling with principalities and powers. Yet the evidence is the same. The wind which bloweth where it listeth may delight the disciple of the Lord Jesus Christ and terrify the animist. In that connection I recall a striking illustration used by Dr. John Kelman, a distinguished Edinburgh divine of a past generation. He was travelling on a liner off the coast of West Africa, when he saw a tropical thunderstorm bursting over the interior. In describing the scene, he remarks on the contrasted emotions which it would awaken in the minds of the aborigines and in those of his fellow-passengers—to the one, a savour of life unto life, and to the other a savour of death unto death. The explanation, of course, lay in the knowledge which Christian civilisation gives. Such instances could be multiplied indefinitely, and they illustrate the saying which has a close bearing on the argument from design in inanimate nature, that the eye only sees what it brings with it to see.

Brigadier N. M. McLeod wrote : I would like to raise one or two points in connection with certain statements made by the author.

1. *On page* he says : " All this motion is, of course, controlled by the sun through *gravitational forces.*"

Should this not read " gravitational and electro-magnetic forces " ?

Gravity can only account for action in one direction, *i.e.*, towards the centre of gravity in direct opposition to centrifugal force.

The force which drives the Solar System and causes the rotation of the planetary bodies is surely an electro-magnetic force, whose mode of action is well described in modern books on electro-magnetism (*vide* " Cosmic Machinery," H. A. Staples).

2. *On page* (*concerning Venus*) : " It has been estimated that the surface temperature is above the boiling point of water."

This I understand is the orthodox opinion on the question ; but I venture to suggest that it should not be accepted without a further examination of the climatic effects to be looked for as the result of the very high angle of axial tilt and other known conditions :—

(1) Axial tilt—about 82°.
(2) Albedo—·76, equal to that of " freshly-fallen snow."
(3) No water, but heavy enveloping cloud of $CO_2$. Rapidly shifting markings, pointing to cloud movements.
(4) Infra-red photo shows an almost completely white surface, but a greyish band at the equator.
(5) No satellites.
(6) Distance from the sun about three-quarters that of the earth's.

In estimating the surface temperature it would appear that the last condition has been given undue weight, whereas the really important factors are (1), (2), (4) and (5).

Let us consider these in turn :—

No. (1).—The tilt of the axis being the most important factor governing seasonal climatic changes, it is obvious that the tilt of 82° must cause the most extreme conditions of summer heat, provided the sun's rays are able to penetrate the thick cloud blanket, and of winter cold. Condition No. (2) tells us that only about one-quarter of the sun's rays reaching the planet can penetrate even the surface of the cloud.

Now if only one-quarter of the rays can penetrate the surface, how much heat can penetrate through the cloud blanket (No. (3)) to the surface of the planet ?

No. (5).—There are no satellites to generate heat by friction.

Is it not much more likely that the surface is coated with solid $CO_2$ over the arctic and antarctic regions, which extend to about 8° from the planet's equator ?

This would appear to be strongly confirmed by infra-red photos (No. (4)).

As regards the surface temperatures of the other planets, the same undue weight seems to be attached to their distance from the sun, and little consideration given to their axial tilts.

Taking, for example, Jupiter, of whose conditions the following is known :—

(1) Axial tilt about 2°.
(2) Albedo—not high.
(3) Water or liquid surface as indicated by an Eastward Equatorial current too slow to be atmospheric. The known presence of a large excess of free hydrogen supports this indication.
(4) Photo shows no ice caps.
(5) Several satellites.
(6) Relatively very distant from the sun.

The effects of these would be :—

Of (1).—Sun's rays reach every point on the surface every day. There is no winter ; in fact, no seasonal changes.

Of (2).—A high proportion of the sun's rays reaching the extensive surface of the planet are absorbed.

Of (5).—Planet receives heat from friction due to rotation of its numerous satellites, and it also becomes highly magnetised.

All these conditions, except (6), would tend to produce a warm or temperate climate.

There seems to be no evidence to support the assumption of extreme cold on Jupiter.

W. T. MARSHALL, Esq., B.Sc., Ph.D., wrote: The words "I believe in God, maker of all things, visible and invisible," are familiar to all, but the "Argument from Design" is generally only applied to "things visible." The beauty of a flower tells of a master hand behind its creation, but Dr. Sutherland, in his very excellent paper, has shown that the same master hand is behind "things invisible." The following interesting points occurred to me on reading it through:

1. The devastating forces of Nature, such as earthquakes, while presenting a problem difficult to explain in the light of beneficent design, give, to my mind, her equivalent of the judgment of God: "Behold the goodness and severity of God."

2. Dr. Sutherland points out that the universe must be designed on a basis of law and order, and that materials must obey certain fundamental laws. He also mentions briefly the structure of the atom, which, as far as we know at present, is a fine example of law and order. The simple atomic weights, the constant valencies, etc., show a beauty and a simplicity which, to my mind, is a strong argument in favour of beneficent design. If animate nature shows such design, then it follows that the atom, of which all substances are made, must be similarly designed, for one cannot conceive of the whole being perfect unless the component parts are perfect also.

3. Generally Dr. Sutherland has pointed out how perfectly balanced inanimate nature is, and how a small percentage difference would make life as we know it impossible. It is to be regretted, therefore, that in his remarks on the effect of the distance from the sun on life he finds it necessary to allow for a 50 per cent. alteration.

In conclusion, I should like to congratulate Dr. Sutherland on his very useful and interesting paper.

Dr. R. E. D. CLARK wrote: Evidences of design in the inorganic world are exceedingly remarkable, of that there can be no shadow of doubt. Yet in attempting to explain them to the layman, scientists are sometimes apt to give a rather wrong impression. If it could be shown that some remarkable purpose was served if a certain algebraic quantity $x$ was equal to 7, it might certainly be urged as an evidence of design. Nevertheless, anyone putting forward this argument would in no way strengthen his case if he urged that $2x = 14$; $3x = 21$, etc., were also remarkable features.

In algebra such a mistake would deceive no one, but in science the mistake may be only too easily overlooked, because it is not always immediately apparent. Yet there surely can be little doubt that some of the instances of design quoted by Dr. Sutherland in his otherwise excellent paper are of this character.

If carbon dioxide is moderately soluble in water to give carbonic acid, and if both calcium carbonate and bicarbonate can be made from the solution, it follows at once that carbonic acid will exert a buffering action—nothing else could be expected. This is certainly no new instance of design, as Dr. Sutherland seems to suggest. Similarly, the mere fact that the atmosphere is made of matter ensures that it will transmit sound; so do all gases, liquids and solids. Again, granted that water possesses some wonderful properties, we may trace many of them to the fact that near the freezing point water molecules are associated, while the resulting large molecules break up before the liquid boils. The fact that the vapour pressure of water rises rapidly with temperature, that the vapour is lighter than air, that water melts at a remarkably high temperature, etc., follow at once from this simple fact, while several other properties are also obviously connected with association. No doubt God, in planning the world, worked out the numerous consequences which would follow if the $H_2O$ molecule were to combine with itself, and designed Nature so that, on the whole, this association would result in enormous advantages. The association is certainly most remarkable and, in view of analogies with other elements, completely unexpected. But to quote the properties of water as if they were *separately* designed is surely misleading. It can only be justified if we urge that the laws governing the inter-relation of the properties of all substances were specially designed in order that they might apply to water. The inter-relations are so remarkable that, unlikely as it seems, this is a *possible* theory; but it is not what Dr. Sutherland has urged.

The danger of making lists of supposedly designed properties of water, etc., is all the more apparent when we consider its effect upon the general public. A good deal of thoughtless "rationalist" propaganda really amounts to this: if God designed all these properties separately, why did He not do so more carefully? Why did He not design the earth so that it should not quake, and why did he not make deuterium common and hydrogen rare (for in *some* respects "heavy water" seems even better designed for life than ordinary water)? Again, if it is really true that water was designed to have a maximum density at 4° C., how is it that this property disappears in the case of salt water, seeing that salt water is so much more abundant than fresh water on the earth's surface? Such questions are bound to raise serious problems so long as Christians forget that inanimate nature is connected by physical laws, and that as a consequence a major advantage may necessarily involve a minor disadvantage, just as the fact that a wheel possessing a circular form precludes it from being square.

As Dr. Sutherland has pointed out, much evidence of inanimate design is to be found in astronomy, geo-physics, and the fundamental properties of the chemical elements. Perhaps there can be no more startling way of presenting this fact than by considering the first nine simplest elements of the periodic system. Of these, four (*hydrogen, helium, carbon, oxygen*) are common in the universe as a whole, and the rest are rare. On the earth's surface, however, *hydrogen, carbon, nitrogen* and *oxygen* are common, while helium and the other elements are rare. Of the nine elements, those possessing properties which seem to be designed for the needs of living organisms are *hydrogen, carbon, nitrogen* and *oxygen* alone, the very same elements which are plentiful on the earth's surface. This, surely, is a most remarkable fact.

## AUTHOR'S REPLY.

Before dealing with the discussion on this paper, I should like to take this opportunity of expressing my gratitude to the Council for their award of the Gunning prize. At the same time, my regret is that circumstances prevented me from being present in person to deliver the paper. The pleasure of attending some meetings of the Institute will have to remain one that I anticipate until better conditions prevail in the political world. I also wish to thank Dr. Palmer for his kindness in summarising and reading the paper for me.

On the comments of Rev. Arthur W. Payne and Rev. Principal Curr I need say nothing, except to thank the authors for their interesting and appreciative remarks.

In connection with Brigadier McLeod's discussion, I am happy to accept his correction, inserting "electro-magnetic" in the description of forces controlling planetary motion. As regards surface conditions on the various planets, his points are very interesting, and seem to suggest that the orthodox views need revision. For the purpose of my paper I used what I believed to be the generally accepted opinions, seeking to avoid issues which might divert from the main line of argument. In any event, it seems safe to conclude that neither Venus nor Jupiter is suitable for life. The argument in this connection is unaffected.

Thanks are also due to Dr. Marshall for his helpful notes. In connection with his last comment I may point out further, that, assuming the ordinary laws of radiation to apply, the distance from the sun does not seem to be a very critical factor in regulating conditions on the earth. It should be remembered that the ellipticity of the earth's orbit is such that our distance from the sun varies from about 91 million miles on January 1st to about 94 million miles on July 3rd each year, in itself an appreciable amount. According to the simple radiation formula as explained in the essay, it thus seems necessary to consider rather large proportional changes, but these are not so great when compared to the distances of other planets.

Dr. Clark has raised difficulties which deserve careful consideration, and warrant a rather lengthy discussion. The main feature of his position that leads to his criticism seems to be that he believes that God was limited in the design of the universe by what we call natural laws, so that He could not make an earth that would not quake, nor salt water that would show a maximum density some degrees above the freezing point, nor the universe generally without what appear to us to be disadvantages. Perhaps Dr. Clark would prefer to say that God designed the natural laws from which, in the main, beneficial results followed, but which also resulted in inevitable disadvantages.

I cannot agree with this, because what we call natural laws are not laws with any inherent necessity, but are merely summary expressions or generalised descriptions of observed phenomena. It is well recognised that these laws have to be revised and modified from time to time as more extended and more accurate observations are made. Pearson, in discussing the omnipotence of God (Exposition of the Creed), observes truly that "whatsoever implieth a contradiction is impossible, and therefore is not within the object of the power of God." Clearly twice seven can be nothing but fourteen, or seven is sometimes not seven. It is beyond the power of God to make it anything else. Similarly, a circular wheel by very definition cannot at the same time be square, though it is quite possible to suppose a wheel to have certain advantages of both forms; but it cannot have both forms. It is, however, quite a different matter to claim any such necessity for natural laws.

A further objection to Dr. Clark's view is that, according to it, the elements of design have to be varied as scientific theory varies. Presumably Dr. Clark would describe evidence of design in water in terms of a remarkable association from which certain advantageous properties inevitably followed. Later scientific theory might be more advanced, and we would have to say that the elements hydrogen and oxygen were designed with a view to certain chemical reactions, and that the properties of the elements were such that liquid water must, by physical law, show association from which in turn its unusual physical properties must follow. Later still, all evidence of design might be found in the electron and other "original" particles. Once given these, the universe, with its advantages and disadvantages, would be inevitable. God Himself could do nothing to change it. The very interesting evidence of design Dr. Clark gives in his last paragraph would, with the rest, cease to have any significance.

In writing the essay I tried to limit myself to statements of observable facts. That water has a maximum density at 4°, that its vapour has a certain low density, etc., are directly observable facts that no one can deny. These properties separately considered are unusual, if not unique, and considered collectively are certainly unique The usual way of making these unique properties consistent with more normal liquids is to assume a certain changing association of the molecules. But this association, while very probable, is not an observable fact, and its relations with the physical properties are not necessary, though we are able to fit them into an order which we designate " law."

Incidentally the fact that sea water does not show the anomalous density change is not an evidence of lack or failure of design. The large bodies of salt water are not in danger of freezing from the bottom up because of other factors. Hence there is not the same necessity for the special regulation as in the case of fresh water.

Similarly, in describing the buffering action of carbon dioxide, it was sought to show how the weak acid formed on solution in water has a remarkably effective action in the processes of metabolism, as well as the previously described geo-chemical action. A chemist would no doubt expect that carbonic acid would show buffer action if given a list of its chemical and physical properties, but to the more general reader such a list would not show beneficent design. Even though it is true, as Dr. Clark says, that, knowing certain properties of carbon dioxide, this action would be expected, it still remains true that no other known substance could replace carbon dioxide for this purpose. The properties of carbon dioxide thus show design as remarkably adapted to the needs of animal life and the requirements of geo-chemistry.

Again, although gases, liquids, and solids generally transmit sound, not all do so to the extent that the atmosphere does, which makes the property a useful one. Rarified gases do not transmit sound appreciably.

Dr. Clark further objects to the listing of properties which seem to show design on the ground that these are only significant if God designed them separately. I am not prepared to say whether they were designed separately or not. It is definite, at least, that with all their various effects they were known to God from the beginning, and the fact that we afterwards observe apparent connections between different properties by no means proves that there was such a connection in the original design.

Although seeking to answer his objections, I wish to make it plain that I appreciate Dr. Clark's criticisms and the spirit in which they were made. I am happy to have them appended to the essay.