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## 858TH ORDINARY GENERAL MEETING

HELD AT THE NATIONAL CLUB, 12, QUEEN ANNE'S GATE,  
LONDON, S.W.1, AT 4.30 P.M. ON APRIL 16TH, 1945.

F. T. FARMER, ESQ., B.Sc., Ph.D., IN THE CHAIR.

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

The CHAIRMAN then called upon Dr. R. E. D. Clark to read his Paper entitled "Modern Science and the Nature of Life."

The Meeting was later thrown open to discussion in which Professor R. O. Kapp, B.Sc., M.I.E.E., Rev. A. W. Payne and Mr. W. M. Powell took part.

Written communications were received from Dr. Julian Huxley, M.A., D.Sc., Dr. Richmond Wheeler, Ph.D., M.Sc., B.A., F.L.S., and Dr. H. Martin Cundy, M.A., Ph.D.

The following elections have been made: D. A. Quadling, Esq., Member; Major C. E. Griffith, late R.A., Member; Basil F. C. Atkinson, Esq., M.A., Ph.D., Member; James Boyce Stonebridge, Esq., Member.

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### MODERN SCIENCE AND THE NATURE OF LIFE.

By ROBERT E. D. CLARK, M.A., Ph.D.

FROM the earliest times the nature of life has offered scope for speculation. An ancient Indian MS asserts that all moving things are alive, while all still things are dead. Some such distinction must have existed in ancient Hebrew thought, for the "living water" of the Old Testament clearly means "moving water." In the middle ages Aquinas tried to state the same distinction more clearly: "Living and non-living things differ in that living things are self-moving in respect of vital functions whereas non-living things are not." For a like reason it was once supposed that the stars were animated, while right up to modern times we read of peasants who, on first seeing a locomotive, declared that it must have horses inside.\*

With the dawn of modern technology emphasis on movement

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\* It is commonly assumed that primitive peoples think of things that move as (1) living and, *therefore*, (2) as endowed with wants and sensations. The fact that among such peoples inanimate objects are often treated as if they were sentient (Hans Kelsen, *Society and Nature*, 1943) supports this view. But this may be a mistake. Until recently, it has been generally assumed that children argue in the same way as primitive peoples, but research has indicated that in the child mind proposition (2) is not a necessary corollary of (1). A young child may argue that a car is "alive" because it moves, but he will nevertheless classify it with unthinking objects such as stones and nails and not with people and animals (I. Huang, *Jour. Genet. Psychol.*, 1943, 63, 71-121 Esp. p. 102). It seems quite possible, therefore, that the description of dead but moving objects as "living" is in no way indicative of an animistic outlook.

naturally declined and other suggestions were put forward. Living things were supposed to be distinguishable because they reproduced themselves (mules do not); fed on their surroundings and grew bigger; responded to stimuli; produced optically active compounds (Pasteur), formed wholes when cut in half at an early stage of their embryonic development (Driesch) or achieved "the active maintenance of normal and specific structure" (J. S. Haldane).

These and all other definitions\* have proved inadequate. Not only can inorganic analogies be found for all of them but it is obvious that every attempt to define life along such lines is doomed to failure. An animal is not less alive than it was before if, for some reason or other, it temporarily loses its power to reproduce, to digest its food or to maintain itself in adverse surroundings. It would be fantastic in the extreme to define a house as a building which emits smoke from its chimney, for if a house could be so *defined* it would normally cease to be a house during the summer time. Yet biological writers in the past have sometimes made this identical mistake in their desire to define life—they have sought to define it in terms of what it can do.

The simple fact is that no definition of life which will stand up to criticism has ever been proposed. This is not, perhaps, altogether surprising. Whatever life may be it is not something which immediately appeals to our ordinary senses—we may *infer* that other people are alive by the way they behave, but we are not directly conscious of the fact that they are alive. At times, inferences are apt to be wrong, so it is no cause for wonder if all attempts to define life in terms of behaviour are misleading.

Clearly, then, we shall have to speak of life as best we can, in the absence of any clear definition as to what we mean by the term. This is not, however, as great a disadvantage as at first sight it may appear. The hunt for definitions has been the curse of philosophy and it is fortunate indeed that science has largely been able to proceed without them. The electronic engineer, for instance, gets on well enough without trying to define rigidly what he means by a "valve" while the chemist does not bother to define "flasks" or "test-tubes" and is unconcerned that earlier attempts to define a compound or a catalyst have

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\* For referenced summary of these, see R. E. D. Clark, *School Science Review*, 1940, p. 1117. Compare also E. Schrödinger (*What is Life?* C.U.P. 1944), who develops the idea that life feeds upon negative entropy.

broken down. Even the physicist only bothers to give extremely rough and ready definitions of his fundamental concepts. Rigid definitions have a way of being so rigid that we create endless confusion by expecting nature to conform to them, instead of learning humbly what nature has to teach us.\* For the time being we must be content, then, to speak of life in the hope that we shall all have at least a rough idea of what we mean by the word.

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If the attempts to define life have been uniformly unsuccessful the same is even more true of attempts to *explain* life in terms of physical and chemical concepts. Yet such attempts have been made in great number. When cyanogen was new to chemistry it was said to be semi-alive, and a primitive "fire-mist" containing the gas was supposed to have made the first germs of life. From that time to the present day, with its supposedly half-alive virus molecules, scarcely a scientific discovery has fired the popular imagination without someone venturing to suggest that it explained life. Optical activity, electricity, magnetism, vibration, radiation, radioactivity, evolution, special atoms with double nuclei which are supposed to have been made when the moon left the earth, molecules called "spirazines," certain types of chemical reactions, coacervates, and even calculating machines have been invoked to explain the mystery. Yet others have sought to avoid the difficulty by asserting that all matter is alive—the mind has been imagined as a mechanism controlled by a few undetermined quanta of energy, atoms have been endowed with sexes and so on.

All these supposedly scientific explanations of life are merely attempts to explain one mystery by means of another. If we do not know how a gas meter works it does not help us very much to be told with a knowing look that "activity" or "rotation" is the explanation unless we can see, at least in a general way,

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\* The dangers associated with an undue desire to define terms have recently been ably discussed by K. J. W. Craik (*The Nature of Explanation*, C.U.P., 1943). For a brief discussion of physical concepts, see later p. 69. The typical attitude of the modern scientist is well shown by the following quotation (W. R. Jones, *Minerals in Industry*, 1943, p. 9): "What is a Mineral? . . . The fact is that it is not possible to give a simple and perfect definition of a mineral, for the good reason that in nature there are few sharp lines of demarcation. The geologist, however, like the child who easily recognises his toys without being able to define them, has a pretty clear conception of what is implied by the term mineral."

how these concepts might explain the functioning of the meter. In the same way, if we do not understand life, our understanding is not enhanced by the magic word "radioactivity" unless we can see how, at least in principle, the splitting of atomic nuclei will give rise to thought, consciousness, growth, etc.

All this is obvious enough and it would scarcely be worth pointing out were it not that some very eminent men have a habit of overlooking it completely. Thus, Dr. Joseph Needham has recently said that: "Biologists find their work is only possible if they *define* (*sic!*) life as a dynamic equilibrium in a polyphasic system consisting of proteins, fats, carbohydrates, lipoids, cycloses and water"—a definition which Sir Charles Sherrington\* considers to be "admirably lucid and comprehensive." But this is neither a definition nor an explanation. No one supposes that a mixture of the substances named, whether brought into "dynamic equilibrium" or not, would necessarily be alive. The statement covers all that we can directly observe in living matter, but that is all: it no more helps us to understand, far less *define*, life than does radioactivity, the calculating machine or the supposed sex of atoms. Our experiences of dynamic equilibria sometimes seem to be connected with growth but they are not connected with consciousness. Finally, it is surely obvious that biologists would not really be put out of work if they were deprived of this supposed definition of life.

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Thus far our discussion has been purely destructive, but it has been vitally necessary to clear the ground. From what we have already seen it would appear at first sight that science has taught us nothing one way or the other about the nature of life. But this is only part of the story. It is certainly true that science has thrown no light upon the *nature* of life in the sense that it has not shown us how the properties of inanimate matter can lead to life. But, on the other hand, it has certainly given us some very definite guidance about the correct manner of approach to our problem.

The history of science shows us that progress is dependent upon the study of extremes. In the early stages of every science investigators asked, for instance, how *strongly* magnetic or electrified bodies (lodestone, amber) differed from other bodies; how

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\* *Man on His Nature*, C.U.P., 1940, p. 83.

black differed from white; colloids from crystalloids; light from darkness and so on. Early progress never came about by asking how one shade of grey differed from a nearly similar adjacent shade or how two suspensions with particles of very nearly equal sizes differed from one another. Explanation and the final unification of science have always come, in the first instance, from the study of exceptional cases in which some property is manifested to a quite unusual degree.

It is true that if we adopt this procedure we may be led at first to imagine a radical difference or *dualism* between things which, as we later learn, actually merge into one another. But it is the mere fact of recognizing the dualism which leads to the final unity, whereas if we start off by imagining a unity before we have evidence of its existence, progress will be impeded. To quote Professor C. D. Broad: "It is much more disastrous to slur over differences which are really irreducible than to recognise differences and wrongly think them to be irreducible. If we make the latter error we still have in hand all the data for the solution of our problem, and we or others will solve it when we have pushed our analysis a little further. But if we make the former mistake, our data are incomplete and the problem cannot possibly be solved until we have recognized the fact."\*

If, then, we wish to treat the problem of life scientifically we must first of all characterize the living and the non-living in terms of observations made upon the most extreme examples of each that we can find—viz., between man and inanimate matter.

When once we do this we see startling evidences of dualism. As was more fully argued in an earlier paper† the laws of inanimate matter all depend upon the fact that events take place at random. But in mind—as developed in man and the higher mammals—we meet the ability to reason and to arrange events so that they do not take place at random. The laws of nature can never produce a petrol engine, a wireless set, an intelligent sentence, or a piece of music. Only because man's mind can conquer the law of randomness is he able to design and create these things.

The conclusion seems inevitable that mind is not, as some maintain, a mere complicated arrangement of organic substances following the ordinary laws of science, but involves a new principle—the principle of planning new arrangements which are not in

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\* *Mind and its Place in Nature*, 1925, p. 12.

† R. E. D. Clark, *Evolution and Entropy*, Trans. Vict. Inst. 1943, 75, 49.

any way consistent with the law of randomness. It is difficult to see any escape from this conclusion except to argue that everything which man creates is "determined" because it is already present in his genetical make-up—a view which creates many more difficulties than it solves.

We are led, then, by the usual scientific procedure to suppose that there is a dualism between mind and matter. Is this dualism final? Or will there come a time when we shall be able to see the unity between the opposites? In answer to this question we can only say that the evidence *at present* available to us indicates that it must be final for the simple reason that mind does not behave in a way that merely happens to be inexplicable to present-day science but involves a principle that it is *contrary* to all scientific generalisations. In this respect the dualism between mind and matter cannot fairly be compared with the less important dualisms of the past which have disappeared with the advance of science.

It seems clear, then, that we ought to accept the evidence as it stands. Even if we still feel that this evidence is not quite conclusive and that there is a slight chance that mind-matter dualism will one day be resolved, we ought still to adopt a philosophy of dualism, at least tentatively, if we wish to be scientific in our attitude. Monism finds no support from scientific method and even in the unlikely event that it should finally turn out to be true, the position of the modern monist is at present indefensible if he claims an empirical basis for his position.

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The conclusion we have now reached is not one which commands assent in all quarters\* and we must now try to understand the point of view of our opponents. We may well imagine one of them saying to us: "Yes, your logic is unassailable, but you are quite out of date. From the time of Descartes up to perhaps fifty years ago dualism was a perfectly sensible point of view. Scientists at that time adopted it tentatively because there were then no known facts which helped them to bridge the gulf between the living and the dead. Today, however, a sharp line of distinction is no longer tenable. Biologists have shown that the living and the dead do as a matter of fact merge into one another and so we know that the world is, after all, monistic."

\* Cf. Julian S. Huxley: "The scientific method . . . rejects dualism . . . nor is there the least reason for postulating any sudden injection of life into our world" (*On Living in a Revolution*, 1944, pp. 44-48).

If we press our critic further he will remind us that there was always the difficulty of plants and trees which—though by general consent alive—show no signs of thought or creative power. He will then proceed to tell us of microbes, bacteriophages and especially the crystallizable viruses which, though they behave like definite chemical compounds, possess the power of reproducing themselves and even of undergoing mutations like the higher forms of life. He will very justly demand to be told how the dualist view which we have reached can survive in view of these and countless other instances which seem so definitely to prove the existence of a gradual transition between the living and the dead.

It is these facts that materialist and monist writers have chiefly in mind when they assert so dogmatically that modern science has vanquished the old dualistic views. The argument is certainly plausible and in view of the frequency and dogmatism with which popular scientific writers have brought it forward, it is little wonder that a section of the public have been led to believe that dualism has been disproved by science. Nevertheless, it is not difficult to show that the argument contains a fallacy which those who use it so confidently have overlooked.

At first sight it appears that our critic is right in asserting that the apparent gradual transition between the living and the dead really does mean that the two are not truly distinct but merge into one another gradually. The history of science affords a number of instances in which pairs of apparent opposites—black and white, acids and bases, complex and double salts, colloids and crystalloids—were once supposed to reveal fundamentally different opposites. But in each of the cases mentioned it has turned out that the distinctions are to some extent arbitrary—there is a gradual transition between the opposite pairs of concepts, so that it is, in some cases, meaningless to say that a given acid, salt, etc., belongs to one or other of the possible classes. Here, then, we have cases in which our inability to classify means that the classification is itself only a matter of convenience and corresponds to no fundamental difference in nature.

Yet, to jump from this fact to the conclusion that the living and the dead are not truly distinct because here also we meet the border-line case where we cannot tell whether an organism is alive or dead is to forget the rules of logic. It is easy to find cases of gradual transition of a very different character. Thus

in everyday life we distinguish between fresh and salt water. As we consider increasingly dilute solutions of salt, there comes a time when we just fail to detect it by taste. At this threshold concentration opinions will vary as to whether or not the water contains salt. Chemical analysis will set a new and lower threshold. Indeed, whatever ordinary criterion we use for the detection of salt, we shall always be faced with a failure to find a definite break between the presence and absence of salt in the water. Here and in many other instances, however, science has shown us that a definite break exists *despite* our inability to recognize it in the laboratory by any simple means. There is a perfectly sharp distinction between pure water and water containing at least *one* molecule of a particular solute. If the dissolved material is a bacillus or virus the distinction may even be of practical importance.

This second possibility is often overlooked. Even scientific workers like N. W. Pirie\* have argued that because *we* cannot distinguish between the living and the dead, nature knows of no such distinction and the words "living" and "lifeless" are but convenient terms with no precise meaning. Yet it is obvious that this conclusion does not follow at all. We cannot be sure that our failure to classify is not due to difficulties of observation rather than to nature's refusal to be classified according to our categories.

On the whole, in fact, past experience does not support the modern monist. At one time it looked as if it was possible to have *any* quantity of liquid in a vessel and that when a liquid flowed it flowed evenly. It was likewise supposed that bodies could be charged with *any* quantity of electricity, or magnetized to *any* degree, or given rotational velocity of *any* amount—all within certain limits. This being so it was considered meaningless to argue that a body was either charged or not charged, magnetized or not magnetized, rotating or not rotating, etc., for there were an infinite number of possible states between the absence and presence of the property in question. But in all these cases the scientists of an earlier day were wrong. For the most part nature seems to work by discreet jumps—there is in fact a real difference between a charged and an uncharged particle: atoms, electrons, magnetons, quanta of energy, etc., cannot simply be

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\* In *Perspectives in Biochemistry*, Ed. J. Needham and D. E. Green, 1937, p. 11.

divided indefinitely.\* The biologist who asserts that the apparent gradual transition between the living and the dead indicates that nature does not know of a discrete "jump" between dead and living matter is ignoring the lessons of the past.

Thus the facts that we have been considering afford no evidence whatsoever against dualism. The grounds for accepting the dualist position are, then, quite unscathed by the new developments and assertions that dualism is out of date often only serve to afford evidence of muddled thinking on the part of those who make them.

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Yet having reached this point, we have admittedly not solved the problem as to whether bacilli, viruses and the rest are, in fact, alive or dead. It can only be said that it would be foolish even to attempt to solve it—for since we lack clear ideas of life it seems inevitable that we shall always be uncertain about what is alive. Nevertheless there are certain important points which ought to be discussed at this point.

We have examined the two possibilities of explaining the fact that there is an *apparent* continuous transition between the living and the dead. At the present time the concept of life lacks precision from a scientific point of view to such an extent that it is not possible to decide between the two possibilities by any known observational means. But let us suppose that one day biologists succeed in overcoming this difficulty and are able to discover a fairly exact definition of life. Will it then be possible to decide finally which of the two possibilities is the correct one?

In looking for an answer to this question, it will be necessary to learn to think in a way which, for many people, may seem a trifle unfamiliar. When we speak of weight, length or electric current we usually think of a *quantity* because we at once associate these things with a pair of scales, a ruler or an ammeter—all of which serve as instruments for measuring. But we must not

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\* As Mr. P. E. Trier has pointed out (*Private communication*) the calculus of continuous variation is always easier than that of finite differences. For this reason, there is in every science a tendency at first to overlook real differences and to assume a continuity which does not in fact exist. It is likely, therefore, that if a means of measuring life (see later, p. 69) were one day to be discovered, mathematically inclined biologists would first of all develop a calculus concerned with its continuous variation and would at first interpret their results in an anti-dualistic sense.

forget that these physical concepts are also *qualities*—weight, for instance, is the quality of being heavy and so on. Conversely, when we think of love, beauty and truth, we instinctively think of them as qualities, for we but rarely think of them in a quantitative connection and so we focus our attention on “what they are” rather than on “how much of them is available.” But here again, these things also have a quantitative side to them—it is meaningful to say that one man is more truthful than another, one picture more beautiful than another and so on.

When we speak of life, it is the qualitative aspect that instinctively comes first to our minds, for here again we have no instrument for measuring magnitude. It is partly for this reason that life is so difficult to define. If we try to give a clear qualitative statement of what we mean by *mass*, we soon find ourselves in deep waters. We usually avoid this difficulty by defining mass as a mere number—we say that a mass is defined by comparing it with a given standard mass or else we discuss how it accelerates under the influence of a force—which also begs the question as to what it is which accelerates. In this way the physicist often shirks the trouble of having to give definitions and thinks of numbers or pointer readings instead.

In the case of life we cannot avoid the difficulty in this way—we cannot say that the life in one fly is precisely 2.38 times that in another fly. So when we try to define life we are forced to give vague qualitative definitions not unlike our tautologous definition of weight as the quality of being heavy.

But even though we cannot measure life it is obvious that it must be intrinsically measurable—just as love, beauty and truth are intrinsically measurable. It is obvious to a child that a hundred live men contain more life than one live man and ninety-nine dead ones. Life must, in fact, have a quantitative aspect and the fact that we do not often think of it in this way is due to our lack of suitable sense organs or suitable instruments and not to the quite absurd possibility that life is a quality without quantity.

It is necessary to emphasize this rather unfamiliar way of looking at life for two reasons. First it shows that the analogy we drew between life and salt water with varying amounts of salt in it affords a very close parallel to what we find in nature. Our perception of life (though reached inductively or intuitively and not through the sense organs) corresponds to our vague sense of taste rather than to the refined methods of the physicist, and

the very vagueness leaves room for differences of opinion. Some living organisms contain more life than others, but as we are not able to perceive life in small quantities we can never reach certainty as to whether it is present or absent in any given case.\*

Secondly, this approach shows us exactly why we experience difficulties in speaking of the so-called non-measurable concepts. It shows us that our difficulties are not necessarily due to the unreality of the concepts we are discussing but are at least as likely to be due to *our* inability to measure these concepts. But this, cosmically speaking, is a purely parochial affair which may only depend upon the anatomy of *homo sapiens*.

The difficulties which some moderns raise about life only show that in their thinking they are putting man in the centre of the cosmos to an even more dangerous degree than did the *savants* of the middle ages. They are saying, in so many words, that what *man* cannot measure is not there.

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\* The general argument remains unaffected if life of more than one kind exists—just as the argument about salt water is unaffected if the salt is not pure sodium chloride but a mixture of several salts. It is also unaffected if life quanta of different sizes (*e.g.*, in mammals and *amœbæ*) exist: energy quanta also may be of different sizes.

#### DISCUSSION.

Professor R. O. KAPP: The subject of this paper is in a sort of no-man's land bordering both on science and philosophy and barely acknowledged by either. It is in a region where amateurs of all kinds may disport themselves unrestrained by the disciplines that exist in those regions where a body of experts have formed means of checking and counterchecking every statement. In such regions the spirit of enquiry is always weak, but there is an abundance of theories; intellectual integrity is less in evidence than imagination; questions are rarely formulated with any care, but the answers to them are given with profusion. It is, therefore, all the more refreshing to listen to an author like Dr. Clark, for whom the spirit of enquiry is the driving force, whose intellectual integrity does not permit him to seek easy solutions, who has here undertaken the rare and hard task of formulating a relevant question.

May I suggest that the question becomes even more relevant, while none of Dr. Clark's meaning is lost, if the word "life" is replaced

by "living substance." If this is done we are left free to reserve the word life for a further question. Are the characteristic properties of living substance due to specific influences that operate on the organic world and not on the inorganic world? If so, we must regard life as cause and living substance as effect. Then two distinct paths of enquiry open up before us. Following the first, we ask what living substance is and does; following the second, what is done to it. The first passes through the well-charted domain of the biological sciences, the second through country at present without maps or signposts.

I doubt whether Dr. Clark's question will ever be answered from a study of mind. This traditional approach has been attempted for too long with too little result. So I think the time has come to try another. One obvious objection to expressing the specific properties of living substance in terms of mind is that most of it has nothing resembling mind. Possession of mind may distinguish a few creatures from the rest of the animal and the whole of the vegetable world; it certainly does not distinguish the organic from the inorganic world.

Can a criterion be found that does this? Can we define a characteristic that is always shown by the organic world, even at its most vegetative, and never by the inorganic world, even at its most sublime? Does any observation prove beyond doubt that something is done to matter when it enters into the organic world that is never done to it in the inorganic world? Only if this can be done are we called upon to speak of life as cause and living substance as effect; only then may we accept the vitalist theory that living substance is due to influences from which lifeless substance is free. Otherwise we must agree with the materialist assertion, at least for the vegetative end of the organic world, that it is attributable to the unaided action of matter on matter.

I think there is such a criterion and that it has hitherto been missed only because we have been looking for it in the wrong place. My suggestion is that the criterion is to be defined in terms of probability. Let me explain.

In the inorganic world, as every physicist knows, things fly about, and jostle, and tumble, and eventually shake down to more or less permanent structures. One can observe certain events, such as the

movement of an electron from one orbit to another in an atom, and certain configurations, such as that of a rock salt crystal. There is a definite probability that a given event or configuration will occur. This can be calculated for very simple cases, and the frequency with which the event or configuration does occur in nature is found to be as predicted by mathematics. It is the firm and well justified belief of physicists that the mathematical calculations based on the theory of probability would always give results that agreed with observation in the inorganic world, even when the mathematics is too complicated for the human brain. In other words physicists work on the basic assumption that the inorganic world is not controlled by any selective principle, but that any event or configuration may occur there that can be attributed to a mere process of shaking down. The assumption is justified by their success.

On this assumption the probability that atoms of two kinds of atoms such as sodium and chlorine will become aligned in the configuration of rock salt crystals if small is still large enough to account for the quantity of these crystals to be found in nature. Physicists have no need to invoke a selective principle in order to explain their abundance. The probability that in shaking down under the unaided action of matter on matter atoms of hydrogen, carbon, nitrogen and oxygen will come into the specific pattern of a given chemical substance is far smaller; the larger the number of atoms that form the given pattern the smaller the probability; and if the pattern is a complex one in three dimensions the probability is smaller still. The probability that mere shaking down in the absence of a selective principle would produce, say, the pattern formed by the millions of atoms in a beach leaf is fantastically small. A small probability but not an impossibility; it is not precluded by physical laws. Mathematics might, *perhaps*, prove that one ought to expect one beach leaf in eternal time. But beach leaves are abundant in *our* time.

What is equally significant is that other configurations, physically equally possible, do not occur. This is why organic matter can never be attributed to a mere process of shaking down. The assumption that there is no selective principle is justified for the inorganic world, while there is overwhelming evidence of a very active selective principle in the organic world.

CHAIRMAN'S REMARKS (Dr. F. T. FARMER) said : I do not intend to make more than a very few remarks on the subject of this paper. I believe it is the duty of a chairman to be brief, and I know there are a number of people here who have contributions to make.

However, I cannot help saying how grateful I am to Dr. Clark for the very valuable paper he has presented to us. The subject of life is probably the most important that men have ever had to consider. Yet for all our closeness of connection with it, it has baffled the greatest intellects throughout the ages, and there seems little reason to suppose that it will ever do anything else. But to correlate the facts that we can understand, and give a balanced view of the whole situation; as Dr. Clark has done so ably, is perhaps the best that anyone could ask with our present limited knowledge.

The temptation to try and explain all phenomena in terms of physical laws has been very great. This is not really to be wondered at when we recall the tremendous triumphs of physics in interpreting the behaviour of material systems. We have been given a key, a *master* key, which turns out to be able to open an immense number of locks, and the view that we have been able to obtain as a result is indeed amazing ; it has certainly surpassed the greatest dreams of the early scientific investigators, and will continue to be a source of wonder as long as its progress is maintained. When we have such a key at our disposal it would indeed be contrary to all our principles of research not to try it in all the locks which we wish to undo. That is natural. But the shock of finding that here and there are some which it does not seem capable of turning should not be allowed to weigh so heavily on our minds as it has done on some people's. The key is our own making, and it is surely more scientific to recognise its limitations than to try all manner of devices to force it where it does not fit. Dr. Clark has done us a great service, I think, in showing how far the laws of physics are relevant to living objects, and at the same time how many of the qualities with which we are so familiar in living beings are just not of the class with which physics can deal, and demand a fresh approach altogether. As Dr. Clark says, a unification may come some day. But for the present, the Dual character of the Universe must be retained, and any denial of this is likely to close the door to further knowledge rather than to open it wider.

The Rev. A. W. PAYNE called attention to the Biblical phrase "the life is in the blood." Mr. Walter Powell also spoke.

#### COMMUNICATIONS.

Dr. H. MARTIN CUNDY, M.A., Ph.D., wrote :—I was much interested in this paper, and in particular in the author's argument that the existence of mind involves a principle which is contrary to all other scientific generalisations. I think this argument is cogent and has never been satisfactorily answered.

I am, however, a little worried about the concluding remarks concerning the supposed quantitative aspect of life. The author was putting it mildly when he said the concept would be found unfamiliar. To my mind his analogies are misleading, but perhaps I have not quite grasped his argument.

Let me say at once that I do not dispute his conclusion. I am convinced that there is a clear-cut distinction between living and non-living, and that the apparent blurring of the distinction is due to lack of refinement both in recognition of the criteria of life and in the means of observation. It is the introduction of the idea of "quantity of life" which worries me, and I do not see its relevance.

The writer affirms that love, beauty and truth are intrinsically measurable. I deny this, in any normal sense of the words. A statement is true, or it is untrue. There are no degrees of truth. When we say that a book, or an argument, or a compound statement is *true*er than another, we mean one of two things: either that it contains more statements which are true, or that it is a closer approximation to the truth. In the latter case it is not *true*. It is obvious that if we say one object is "more living" than another we do not mean it is a closer approximation to life. We could say this of a robot or a machine, but not of anything we suspected of being alive. We can only mean that the object "contains more elements which are alive." Again we can speak of a man as more truthful, but surely "veracity" is the quality here predicated, and not truth. We mean merely that he more consistently tells the truth. What is here measurable is *frequency*.

In the same way, an action shows love, or it does not. When we say a man, or an action is more loving than another, we mean that

he or it applies the principle of love in more detail, with reference to more people or contingencies than the other. We could say then that an object was "more living" than another if it reacted as a living thing to more details of its environment. The case of beauty is more difficult, but I think can be subjected to the same analysis.

In none of these cases are there any grounds for speaking of a "quantity of truth" or a "quantity of love" or a "quantity of life." To speak of such a quantity we must show that it can be added or subtracted in the same object. There is only "more life" in 100 men than in one man, because there are more living objects.

Are 100 metre-sticks "longer" than one metre-stick? I think not. They are all the same length, that is all that can be said. If we place them *end to end* so as to measure, or to form, one extended object, then they are 100 times as long. But this is just what we cannot do with life. We can take 100 living cells together in a colony, but we have added the *living units*, not the "units-of-life." We cannot add life in the same object. I do not mean just that we are incapable, I mean the whole idea is inconceivable.

Life is like truth, and beauty, and love. It is a quality which is not capable of measurement, and therefore it does not belong to the world of physics or exact science. Living cells are additive in the same way as true statements or loving deeds are additive; but the life and the truth and the love are not additive quantities in any sense. From the same analogy we see that life is a quality which is either possessed or not possessed by any given object. There are no degrees of life. (There may, of course, be different *kinds* of life.)

This is, of course, an analogy and not an argument. I am merely at pains to point out that it seems to me wrong to think of life as a measurable quantity, and thus expect it to be brought into the realm of science. I reach the same conclusion as the writer of the paper by thinking of life as above and outside the realm of the exact sciences, instead of thinking of our uncertainty as due to our lack of refinements of measurement. This uncertainty relates only to the recognition of the criteria of life, not to life itself.

DR. L. RICHMOND WHEELER, Ph.D., M.Sc., F.L.S., wrote: This

is an interesting and scholarly paper, and I am in general agreement with Dr. Clark's conclusions, particularly that dualism is not disproved by modern (or ancient) monistic theories.

But the Nature of Life is a very big subject to be tackled in a short paper, or in still shorter comments, and I think Dr. Clark has weakened the vitalist position unnecessarily by taking definitions of life based on single propositions only, and then accepting the materialist thesis that each one of them, taken singly, has failed.

Nor does his previous treatment in *School Science Review*, 1940, p. 1,117, throw much further light on this crucial matter. For example, he quotes, apparently with approval, the statement by Lotka that chloroform "feeds" on shellac and ejects "undigested" glass, and that this and similar phenomena are homologous with the complex processes by which organisms absorb, digest, and build up into their own varied substances the quite different matters they obtain from the inorganic environment or from vegetable substances previously elaborated in that way. But, does chloroform elaborate (or degrade) chloroform from shellac? I submit there is no homology whatsoever between simple physical aggregations such as solutions and the anabolism performed by plants and animals.

Biogenesis remains an unbroken law of Nature, supported by millions of experimental facts. Viruses exist and reproduce only where there is living substance to support them: Hopkins, Kenneth Smith, and other experts say viruses cannot be looked on as links between the living and the non-living in our present state of knowledge.

In addition to the two criteria of nutrition and biogenesis, many more can be given as differentia between organisms and non-living matter. Where several of these occur, life is present; where only one or two, and those usually in feeble analogies, such as the growth of crystals by aggregation of particles of their own composition, life and its many mysteries are absent.

Dr. JULIAN S. HUXLEY, wrote: I fear I cannot be present on April 16th, and also find myself unable to comment on Dr. Clarke's paper, as to do so adequately would take far too much space. I would like, however, to draw attention to one point. Dr. Clark discusses the question of measuring life quantitatively. He seems,

however, to leave overlooked the point that many biologists would regard "life" merely as a convenient word used to denote the ensemble of living organisms and their properties. Life as an actual entity then has no more real existence than *e.g.*, did the "caloric" of the 18th century as a substance. If so, "life" cannot be measured (though evolutionary progress may be).

Mr. TITTERINGTON writes: Dr. Clark has confined his discussion to the distinction between the living and the dead, or not-living. But we use the term "living" in various senses. We say that a tree is living, and that an animal is living, but that a stone is not living. But when we say that an animal is living, we do not mean the same as we do when we say this of a tree; we recognise a discontinuity between the life of a vegetable and of a animal, in the same manner as we recognise a discontinuity between the vegetable and the stone. But just as it is not an easy matter to determine precisely where to draw the boundary line between dead matter and living, or to define exactly what it is that constitutes the difference, so it is not always easy to say whether a given organism is an animal or a plant, or what it is that makes an animal an animal. An animal exhibits reflex action, but so do some plants, such as the sensitive plant and the sundew. In the higher forms of life we recognise feeling, volition and at least some rudiments of reason, but not so in the lower ranges. A sea anemone (perhaps this may not be a very good example) seems to feel, but can we be sure that the reflex action we observe is fundamentally different from that of the plants we have cited?

I forbear to speak further of the discontinuity between the animals and man "made in the image of God," but as regards that between plant and animal, it would be interesting to hear what Dr. Clark has to say, if it is not trespassing too far outside the limits he has set himself.

#### AUTHOR'S REPLY.

I am most grateful to all who have taken part in this discussion. Many of the points raised are most interesting, but there is only space to allude to a few of them here.

Professor Kapp (whose deeply interesting book, *Science versus Materialism*, 1940, should be consulted for further details of his views) suggests that living and non-living substances ought to be distinguished, not by the presence or absence of mind, but by the presence or absence of a "selective principle" working against the probability laws. He holds that in this way alone can we explain the fact that plants are obviously alive but equally obviously devoid of mind.

Now a selective principle need not necessarily be present in objects, such as machines, which are constructed in defiance of probability laws. A selective principle (in this case a mind) is necessary for the creation of an original design, but not for the mere existence of the object designed nor (so far as I can see) for its reproduction if it is capable of reproducing itself. So if we postulate a non-mindlike selective principle present in living substance, I do not see why a machine should not also be regarded as living. We have the added difficulty that a selective agent which is not a mind is quite outside anything of which we have experience, and is, indeed, unimaginable. On the whole, the traditional distinction between mind and non-mind would seem to offer fewer difficulties. Nevertheless Professor Kapp's suggestions are well worth exploring further.

Dr. Huxley thinks I have overlooked the fact that many biologists use "life" as a convenient word "to denote the ensemble of living organisms and their properties." He then concludes that "life" has "no more real existence than" the 18th century "caloric."

I regret that I cannot follow this reasoning. I neither doubted nor overlooked (*see* p. 67) the fact to which Dr. Huxley draws attention. To say that "life" is unreal because it describes organisms that are "living" does not, as I see it, throw much light on the matter. I do not understand in what way "caloric" illustrates Dr. Huxley's point. It was once supposed that hot bodies differed from cold ones by the presence of "caloric" and it was hoped that this caloric would one day prove to be measurable. The physical entity which distinguishes hot from cold bodies was later identified with the kinetic energy of molecules and this *can* be measured. So the factor which distinguishes hot from cold bodies is measured in degrees of temperature or in energy units per molecule instead of in grammes

of a material substance. The mistake 18th century scientists made was to suppose that caloric would prove to be measurable in grammes, but in my paper I have made no assumption as to the units in which "life" might prove to be measurable. The postulate of an entity which distinguishes hot from cold bodies was a piece of sound physical intuition. No one would think of saying that heat (or caloric—call it what one will) "has no real existence" because it denotes "the ensemble of hot substances and their properties." Dr. Huxley does not explain why he argues in this way about life.

I think Dr. Wheeler's criticisms are due to a misunderstanding. I do not for one moment wish to suggest that the simple physical phenomena that Dr. Wheeler mentions are truly analogous to living processes, far less do I wish to weaken the vitalist position by the use of such analogies. I have rather been at pains to show that *even if* the materialist is allowed to "get away with" all these bad analogies, the existence of mind will still, ultimately, make his case indefensible.

I am most grateful to Dr. Cundy for his thought-provoking criticisms of my remarks about the quantitative aspects of love, beauty, truth and life. I am sure that his disagreement with what I have said is largely my fault. I omitted to state that measurement always involves an operation. 100 metre rules have no more length than one such rule unless we *also* specify that they shall, in imagination if not in reality, be joined end to end. When we speak of a kilometre or a light year we have an operation of this kind in mind as, indeed, we always have when we think of any measurement whatsoever.

Bearing this point in mind, it seems to me that Dr. Cundy's objections could be applied equally well to purely physical qualities—as indeed he has himself realised in the case of length. One might argue, for instance, that since 100 batteries contain no more potential than a single battery, the whole idea of measuring potential is inconceivable. But this conclusion would be wrong.

The question is—can we *conceive* of operations which would render elements of love, etc., additive within a single mind? It seems to me that we obviously can. In this case of love and beauty such conditions are fulfilled spontaneously in our minds every day of our lives—in the *growing* love we feel for our friends, in musical and artistic appreciation, etc. It is an over simplification to say that

we either do or do not perform an action out of love for another person. There *are* degrees of love. As for truth—if truth simply means true statements, Dr. Cundy's objections are partly justified—but I did not intend to confine the word within these narrow limits. Dr. Cundy, however, concludes that by "more alive" I can only mean "contains more elements which are alive." I do not see why he should object to this. We can measure electric charge and mass by the number of elements (electrons, atoms) of these which a body contains. Similarly if the life of an organism turned out to consist of an integrated group of life elements, life would have as much right to be called measurable as electricity or mass. Even the integration of the elements might also be measured by a probability (*Cf.* entropy).

Of course, *strictly speaking*, physical quantities are never really *numbers* since all measurement consists of a manipulation of numbers. So ultimately all measurement, other than that of numbers, is inconceivable. I think this fact lies at the back of Dr. Cundy's objections. Nevertheless I do not see that he has brought forward any reason for doubting that love, beauty and life are any less potentially measurable than the quantities with which physics deals.