# BASIC DYADS IN CONTEMPORARY PHYSICS

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In his inaugural dissertation as Professor of Theoretical Physics in the University of London, Professor Bohm raised the question whether connectedness may not be a more fundamental concept than existence itself. He concluded his address: "the discrete topological theory discussed here does suggest at least one new kind of question. For since it implies that what is fundamental is the link, we should therefore try to find experiments that disclose the relationship of linkage itself, rather than the structure of particles, which is only a very indirect consequence of the basic characteristics of the linkages. It is at present too early to suggest such an experiment, because first one must familiarize oneself with how the theory deals with some of the older questions (as was in fact also necessary with the quantum theory, before it could lead to the framing of new kinds of experimental problems). However, one can say at present that some directions in which such experiments may be possible can already be discerned. It may be hoped that eventually these questions will be clarified."

The following article develops further the view that the particular kind of connectedness associated with complementary dyads is derived from the fundamentally discrete nature of experience itself. The article being a development of the notions introduced in the inaugural dissertation, and reference should be made to the latter for more detailed argument in support of the thesis that linkage and action are prior to objects and states.

## 1. Movement vs. Rest

Briefly, what we have done is to turn our customary modes of thinking around with reference to certain basic questions. The most fundamental of these questions is that of the nature of movement and rest.

Now, our usual mode of thought is based on the implicit assumption that what is is a totality of permanently existing substance, in the form of a collection of objects of various kinds. In a short interval of time each of these objects is supposed to suffer a series of quantitatively small changes, passing through a non-countable infinity of qualitatively similar intermediate stages.

In the point of view suggested in the talk, however, we assume that what is is a totality of elementary quantum processes. That is, we begin with movement itself, regarded as discrete, and yet unbroken in the sense that division will, in general, lead ultimately to qualitative change. This movement is then to be understood as a total process, which is to be analysed in terms of the relationships, orders and structures that are in it. The "permanent" object is then abstracted from this totality as a relatively invariant repetitive pattern in the whole process.

This problem is an old one. Thus, more than two thousand years ago, Zeno showed that the attempt to think of movement in the customary way leads to paradoxes. As an example, he considered an arrow in flight. It is supposed to occupy a series of successive positions. But while it occupies a particular position, we conceive it as fixed, and thus we deny the idea that it is moving. By means of this and other similar paradoxes, Zeno demonstrated that our concept of movement is beset with contradictions.

These contradictions have not yet been resolved, but what has in fact happened is that scientists have adjusted their ideas to accommodate these contradictions, as well as they can. The differential calculus is an example of such an adjustment. One considers an interval, t, and the value of some function, f(t), at the beginning and end of the interval. One then imagines the interval to decrease to zero as a limit, and in this way, one obtains the derivative of the function. But this limiting process is full of logical difficulties. In general, it has meaning (when applied repeatedly) only for a limited class of analytic functions. But no real movement is known that is described exactly by this class of functions. Thus, a typical particle executing Brownian motion, quantum fluctuations, etc., has a movement which is so discontinuous in the small that the limiting process of the differential calculus is meaningless when applied to it. At best, this calculus is valid as a simplification and an approximation, applicable in certain limiting cases. But any attempt to push it too far leads to contradictions and absurdities as well as indications that its basic assumptions are always false, in a deep sense. [A special case in the infinities of modem quantum mechanical field theories.]

Now, as has been indicated already in the talk, in every mathematical theory, one must begin with something, taken as axiomatic. If one begins with process, i.e., with the assumption that what is is movement itself, then no paradox arises. For this assumption does not contradict the fact that some things are seen to be at rest. Indeed, in this point of view, a state of rest is comprehended as the result of invariant relationships in the repetition of similar features of the total movement in a process. On the other hand, if we begin with rest, then we have denied movement from the start. Any attempt to bring in movement and change must then lead to a logical contradiction, to which we can at best "adjust", by means such as the differential calculus, which permit the correct treatment of a certain limited range of problems, despite the contradiction.

In discussing process, it is essential to stress that movement is being taken in its general sense of change, qualitative and quantitative, rather than in its more specialized sense of displacement of a permanent object through space to which latter we shall hereafter refer as "motion". Thus, one may discuss the "movement of a symphony" as a related, ordered and patterned whole, the essential character of which is contained in its total structure. On the other hand, the "motion" of a symphony would be meaningless (except perhaps in the sense of the orchestra playing the symphony and being at the same time transported through space). In a similar way, we have been proposing that the essential character of the electrons, protons and other entities going all the way up to large-scale objects, is determined in a totality of related, ordered and patterned process-structure, so that, for example, the fact that there is an electron means that a certain movement of such a kind is being executed in the totality (as one could say that a certain theme is being carried along in a symphony). It must be emphasized that even the "resting electron" is actually constituted of such a pattern of movement which, however, returns to its original form again and again so rapidly that no change is manifested on the large scale.

As shown in the theory of relativity, an object at rest has a great deal of internal energy, a part of which can for example be liberated in a nuclear transformation. Indeed, the whole of this rest energy is made available when a particle meets the corresponding antiparticle and the two annihilate each other. If we conceived each of the particles as a "permanent object", this process would indeed be incomprehensible. On the other hand, if, as has been suggested here, we regard each particle as an invariant repetitive feature of the movement constituting the total universal process-structure, then it is evident that, under suitable conditions, two opposite patterns of movement, corresponding to particle and antiparticle, can cancel each other.

We emphasize then that in this point of view, movement is taken to be universally what is and needing no explanation, while it is always rest that needs a further explanation. Such an explanation is carried out in terms of the notion of invariant repetitive, ordered, and structured relationships that hold only relative to certain conditions, at certain levels, within specific contexts, and to limited degrees of approximation.

It is evident that relationships of the kind described above arise quite naturally in the study of movement. For in a given period, region or domain or degree of approximation, each movement can be characterized by relationships that are invariant within the specified limits. But it is characteristic of movement that all of its features can alter.

Thus beyond the limits in question, there is bound ultimately to be a change in the relationships that are invariant in the narrower context. This change of relationship is in turn a relationship of a higher order. (As the velocity of an object, itself a relationship, can alter, giving rise to a new aspect of the movement, the acceleration, which is a relationship of velocities at neighbouring intervals of time.) Thus, if we start with movement, defined through relationships, we can then go on to the movement of movements, translated mathematically as relationship of relationships coming ultimately to the structure-process that enables us to understand the very constitution and basic qualities of what we have previously thought of as permanent objects.

On the other hand, if we start with the idea of a permanent object, there is no correspondingly natural way of applying the concept of the object to itself (i.e., an object of objects) to obtain the concept of movement. Rather, movement must be introduced arbitrarily; and as we have seen, this leads ultimately to contradictions. So to begin with, movement as a basic concept generally has a greater explanatory and predictive power, as well as greater logical coherence, than to begin with the permanent object as a basic concept.

We emphasize, then, that in the problem of movement and rest, we are dealing with a typical case of a kind of contradiction that is widespread in physics, and indeed, seems to be built into the very structure of our common language. For it is customary to suppose that the notions of rest and movement exclude each other, i.e., that what is at rest is not in movement, and what is moving is not at rest. But here, we are in effect proposing that far from contradicting movement in its general sense of ordered and related qualitative and quantitative changes in a total structure-process, rest is actually an aspect and indeed a special case of movement.

There are a great many other examples of pairs of concepts that are customarily taken to be contradictory and mutually exclusive, but which should more logically be treated either by regarding one member of the pair as an aspect or special case of the other or by regarding both as aspects of a broader and more comprehensive concept. In addition to movement and rest, such pairs include connection and separation, discontinuity and continuity, difference and similarity, asymmetry and symmetry, order and disorder, as well as others. Each one of these pairs of concepts plays a key role in the understanding o( the universal structure-process referred to in the talk, and in fact, the whole set of these lies at the basis of the topology and geometry of space-time. In the subsequent work, we shall therefore go into these concepts in more detail.

2. Connection vs. Separation

In the talk, we have already seen that if interval is taken to be a basic concept, then any two aspects of the total structure are connected by a series of linkages. But each linkage not only connects; in the very same action it also separates. Indeed, no matter how close two different aspects of the process are, they must be separated by at least the indivisible link that connects them. And if two entities are distant from each other this means only that they are separated by a series of many linkages.

To talk about something that is totally disconnected from the universe would evidently be meaningless, since it could never enter our experience in any way whatsoever, nor could it have relevance for anything that could ever be known by us. Therefore, it makes no sense to regard separation as a concept that totally denies or contradicts connection. Rather, separation is a necessary aspect of all connections, an aspect that is emphasized in a long series of linkages, and minimized in a short series. To assert a contradiction between separation and connection, as is implicit in much of our common usage of the words, is therefore likely to create confusion in our thinking about the subject.

3. Continuity vs. Discontinuity

A pair of relationships closely allied to connection and separation is constituted by continuity and discontinuity. The elementary process, linkage, or connection that is fundamental in the quantum mechanical domain is discrete, and therefore, is not in the usual sense of the word, continuous. That is, it does not pass through a continuous infinity of qualitatively similar points, preserving its identity while doing so. Nor is it continuous in the sense that something in particular is continued inside the interval. But because between the beginning and the end of an elementary linkage there is an unbroken structure of qualitatively different kinds of processes, such a quantum connection is also not discontinuous. (In the talk we gave a similar example, of the interval between words, which is unbroken, and which is nevertheless not words). Let us then refer to the elementary process as a-continuous, to indicate that its basic qualities go beyond the question of continuity and discontinuity. As explained in the talk, continuity then arises when similar structures are continued over a number of linkages, while discontinuity arises when such a relationship of continuity comes to an end.

It can be seen that the concepts of continuity and discontinuity play complementary parts in the understanding of structure-process. Thus, in the example given in the talk, the electron process was compared to a structure of similar linkages, the similarity being visualized by thinking of a set of links of the same colour. The electron is then understood through the continuity of a certain pattern. Yet, it is also the discontinuity of this pattern, in another sense. For unless the electron structure were different to that in the immediate neighbourhood, there would only be a homogeneous mass of linkages, in which no entities of any kind could be distinguished at all. So there is a discontinuity in certain kinds of connection (e.g., to neighbouring particles), and a continuity in other orders (e.g., time), which is necessary for the electron to be what it is. Moreover, even the continuous aspects will eventually come to an end, giving rise to further discontinuities (e.g., an electron can meet its antiparticle and be annihilated); while the discontinuous can be the basis of further continuity (e.g., a regul ar pattern of discrete but similar atoms in space gives rise to a continuing lattice structure). So continuity and discontinuity are not absolute qualities. Rather, they are ever-changing roles, that are now filled by one aspect of a structure, and now by another, the important point being that no theory with any real content can be made which does not somewhere include both roles. There is then no aspect of any entity, property, process, relationship, etc., which it not both continuous and discontinuous, when the problem is considered as a whole, and not just in some partial view.

4. Difference vs. Similarity

As the suppositions that separation contradicts connection, and continuity contradicts discontinuity, lead to confusion, so does also the assumption that similarity contradicts difference. Thus, if there are two things. A and B, they must be different. If there were no difference at all between them (at least, for example, in position), they would be the same: and therefore, in reality, A and B would have to be just two names or labels for one thing.

Two different things can however be similar in certain respects, e.g., their colours or shapes. They may be so similar that, in a certain level of approximation, no detectable differences exist in these respects. Then they are said to be equivalent or equal. But equivalence is a relationship between different things, and not an assertion of identity. Indeed, the phrase, "identity of different things" is evidently an absurdity since "identity" means "being the same thing".

Not even two quantities on opposite sides of an equation are identical in their meanings. For each quantity is generally defined and obtained in a different way (e.g., on one side of the equation, a function may be obtained from a power series, and on another side from an integral). Besides, the domain of definition of the functions appearing on the two sides of an equation is generally different. What indeed would be the use of an equation, if it only asserted that a thing named A is the same thing as a thing named B? That would amount to the trivial statement that people have called one thing by two names, A and B. In reality, an equation is non-trivial only because it asserts the relative and limited equivalence of two different mathematical entities defined in different ways, in different overall domains, etc.

It seems clear then that similarity, equivalence and equality are special aspects of difference, i.e., they represent a difference that makes no difference, in certain specified, limited and defined senses. This point of view is implicit in much of modern mathematics, in which the notion of equality is replaced by that of equivalence relations (e.g., in group theory), which latter are a special case of non-equivalence relations (e.g., relationships implying order such as "greater than"). Indeed, it may be said that mathematics should no longer be expressed in terms of equations, but rather by the assertion of relationships between elements and aspects that are all different. And as has been indicated in the talk, the relationships of these relationships give rise to orders, while the orders of orders lead to pattern and structure.

This brings us to the very interesting problem of how mathematics is related to physics and to our general experience with the world as a whole. Here, one may reasonably suggest that such a relationship is possible, only because in mathematics, man has created abstract structures which are similar to actual structures found in experience. For example, the electric field structure calculated from Laplace's equation is similar to that obtained by measuring an actual field. And in the talk, we have tried to indicate how to go further, to relate certain algebraic structures to the total space-time structure of the universe.

The above helps to explain why mathematics has been so powerful in predicting new things in physics. For if we can hit on an abstract mathematical structure similar to some actual structure, then from some observations on the actual structure, we can often get a valid idea of what new possibilities to expect, for aspects of this structure not hitherto observed.

5. Symmetry and Asymmetry

We now come to the problem of symmetry and asymmetry. Thus far, these too have usually been regarded as mutually exclusive concepts. This procedure has led to very serious difficulties in modem physics which centre on the question of how the observed irreversibility of the macroscopic physical laws can be reconciled with the reversibility of the corresponding microscopic laws.

Now, it is an evident fact that movement on the large scale is irreversible. Each new moment is different to what came before, and what is past never comes back again exactly as it was. In physics, this irreversibility shows up in the second law of thermodynamics, which is based on the fact that heat flows from a region of higher temperature to one of lower temperature and never the other way round. In addition, there is the closely allied phenomenon of friction, in which mechanical energy can be turned completely into an equivalent amount of heat energy; whereas it is not possible to reverse the process and to turn heat energy completely into mechanical energy. (An engine permits only a partial reversal, because as can be shown from the second law of thermodynamics, its efficiency must be less than 100%.) More generally the irreversiblity of all physical processes is comprehended in the notion that a certain abstract property called the entropy can only increase, and can never decrease, in any movement or change taking place in an isolated system.

On the other hand, the laws of microphysics are completely reversible, in the sense that if the movements of all particles and fields in the universe were reversed at some instant, the system would execute an opposite order of development relative to the original. For example. , if all the movements of molecules were to reverse, it would in principle be possible according to the micro-physical laws, for a kettle of water on a fire to freeze, transferring its heat back to the flame.

Large-scale irreversibility has been related to micro-reversibility by means of probability concepts. In this point of view, heat is regarded as a kind of random or disordered molecular motion. In friction, for example, ordered mechanical energy is transformed into disordered molecular energy on the micro-level, where it is lost to view as large-scale movement, and appears in our grosser observations only as heat. More generally, the entropy of a system is defined in terms of a certain mathematical measure of the degree of disorder in its movement and structure at the molecular level. Then, on the basis of certain assumptions about the probabilities that seem to be reasonable, at least at first sight, it follows that a process in which ordered macroscopic movements become degraded into disordered molecular movements has a very much higher probability than for the reverse to happen. A theory has been developed along these lines, which explains flow of heat from a higher to a lower temperature, frictional transformations of mechanical energy into heat, and the general tendency for entropy to increase, as results that are so overwhelmingly probable that for practical purposes, we can consider the laws of thermodynamics to be deterministic predictions.

Although current probability theories do permit the correct calculation of many thermodynamic properties of matter, they suffer from an inherent ambiguity and confusion in their basic premises. This is shown up by certain paradoxes, such as those associated with what is called the Boltzman's H theorem, which make it clear that on a more careful study of the implications of these theories, the apparent proof of irreversibility based on probability breaks down (eg., it is demonstrated that it is in reality just as likely that the entropy will decrease with time as that it will increase). When one pursues such studies further, one finds that current theories never really manage to get macroscopic irreversibility out of microscopic reversibility; they simply push the logical difficulties off into some obscure part of the theory where they are not easy to see (rather like sweeping the dust under the carpet).

In the point of view discussed in this talk, however, we do not begin with the assumption of reversibility. Rather, we assume from the start that the basic linkages of elementary processes are directed in the sense that the beginning and the end of such a process are clearly definable. We can meaningfully do this, because the interval inside such a linkage contains a lower level structure, which need not, in general, be symmetrical with regard to the two possible directions in which the process can be considered. Moreover, we are regarding the so-called "elementary particles" as just abstractions from the total process. We therefore do not begin as is usually done in physics with a collection of interacting elementary particles and try from these to build up a model of the whole universe. Rather, we begin with the total process and treat the elementary particles as very special features that are relevant when we are studying, certain minute aspects of this process in some kind of relative isolation. It is not at all unreasonable to suppose that these partial, limited, and relatively isolated aspects are symmetrical, while the process as a whole is not. So we encounter no difficulties in comprehending the over-all asymmetry of development in time (e.g.. that implied in the irreversibility of thermodynamic processes). For we begin with such asymmetry as basic. We also encounter no difficulties in understanding the symmetry of the laws of movements of elementary particles; for asymmetry always contains symmetry as a special case. On the other hand, once we begin with the general assumption of symmetry, then we have contradicted asymmetry, and it is not really possible to get the latter back in a fully coherent logical way.

More generally, we are led to regard symmetry as a special case of asymmetry, wherever it appears. This notion is particularly significant in the consideration of certain problems arising in the theory of elementary particles. One of the most striking facts discovered in this theory relates to the particle antiparticle problem already referred to in the talk. It is this:

The wave equation for an antiparticle is obtained from that for the corresponding particle by a reflection in time, a reflection in space, and the interchange of the roles of the beginning and the end of a physical process. (Mathematically, the latter corresponds to an interchange of ingoing and outgoing waves).

This fact was most surprising when first discovered, as it implies that the basic laws of physics are not symmetrical under mirror reflection alone (this lack of mirror symmetry showed up in the non-conservation of parity). Rather, they are found to be symmetrical in a subtler sense, in which time reversal and exchange of particle for antiparticle must be combined with space reflection to obtain the symmetry in question. Roughly speaking, this means that at the level of elementary particles, there is a qualitative physical distinction between a given process and its mirror image, in the sense that one of these constitutes a different kind of particle that will, for example, annihilate the other (whereas in terms of previous physical ideas, mirror image systems should, as in everyday experience, be qualitatively similar to the original and without this feature of mutual annihilation).

Now, in our point of view, symmetry is always to be understood as a special kind of asymmetry, defined by suitable relationships. Here, the operative aspect of the term "symmetry" is the last part, i.e., "metry", meaning "measure" or "metric". That is to say, a symmetrical figure is one possessing different aspects with equal measure (e.g., an equilateral triangle). As such, it is evidently a special case of a figure whose different aspects do not have equal measure, and which is therefor asymmetrical in its structure. So the question of symmetry is inseparably related to that of metric.

If one goes to general relativity, one sees the problem more clearly still. For here, there is a "metrical tensor", (). which specifies how the co-ordinate differences () are to be related to actual lengths, ds, (through relationship, $ds^2 =$ ). Without this tensor, it would be impossible to say what symmetry even means, because this tensor determines which lines are equal in length, which are perpendicular to each other, which are parallel, etc. [E.g., if we want to construct a figure with reflectional symmetry, we need equal lines that are perpendicular to the planes of reflection, and these are determined by the metric tensor.]

Now, in any case, we are going to interpret elementary particles as invariant repetitive aspects of the total process structure (e.g., such as the dislocations referred to in the talk). To fit the observed facts about particle and antiparticle described earlier, these aspects will have to have suitable symmetry properties, and will therefore be deeply related to the metrical properties of space. But the fact that symmetry properties have a new physical significance suggests that it may be more fruitful to turn the problem around, and to regard the symmetry of basic structures as the fundamental starting point, from which the usual metrical properties of space will follow as consequences.

In the talk, we have already indicated that the metric is defined when we can divide an arbitrary line in two. But a line can be divided in two, if we know what is meant by a perpendicular plane, such that the length of the reflection of each half in this plane is equal to that of the other. And if the basic structure of space-time is such as to determine what are the relationships of reflection for all space-time structures, then the metric is implicit in the symmetry properties of the elementary particles. Moreover, the peculiar connection between reflected process structures and antiparticles is now clear. For a completely reflected process-structure will have all its constituent movements the reverse of those of the original, so that the two will naturally combine to produce no movement at all on this level, thus annihilating each other.

7. Order vs. Disorder

The problem of symmetry and asymmetry of process in time is deeply related to that of order and disorder. For as we have seen, the irreversibility of large-scale physical phenomena is now regarded as the result of a tendency for relatively isolated aspects of a structure-process to develop toward states of greater disorder with the passage of time. However, as we have pointed out, current attempts to treat this problem by probability concepts are seen to lead to confusion when the basis of the theory is scrutinized with care. The source of this confusion can be traced to an unclear notion of the meanings of the terms, order and disorder, arising largely in the tacit assumption that these two ideas are mutually exclusive, and therefore contradict each other.

The problem of order and disorder already arises in the discussion of the foundation of our conceptions of probability. Consider, for example, a game of coin throws (a typical case in which one can apply the theory of probability). It is generally asserted that the succession of heads and tails in such a series of throws is disordered, irregular, random, etc., while the statistical average frequencies of heads and tails tend to approach definite values, given by their probabilities (in this case, half for heads and half for tails, if the coin is well-balanced). However, when we come to define what could be meant by the terms disordered, irregular, random, etc., we find great difficulties. Thus, randomness has often been identified with lawlessness or featurelessness. But the mere negation of laws or features is not enough, because it is necessary also to assert some positive qualities of a random array, to distinguish it from anything else whatsoever. But once we try to define randomness positively as well as negatively, we will inevitably attribute to it some kind of law, feature, order and regularity. Thus, we come to the absurd concept of a law of lawlessness, a feature of featurelessness, etc., in which the first term contradicts the second. Indeed, as one can easily see by reflecting a little on this problem, it is impossible for anything at all to exist unless it has some kind of feature, order, regularity and law. So featurelessness, disorder irregularity, lawlessness, etc., can have meaning only in some relative and limited contexts, and can in no sense be regarded as absolute. (E.g., as the order of coin throws may be irregular in relation to the time order of throwing, but not in relation to the precise initial position and velocities of the coins after they are released.) Order and disorder are therefore not mutually eclusive and totally contradictory absolutes. Rather, they are complementary pairs of related concepts, which, like continuity and discontinuity, connection and separation, etc., arise together in every attempt to discuss a real situation.

To see the meanings of the notion of order and disorder more clearly, let us return to the discussion given in the talk, in which order was analysed in terms of the relationship of relationships (e.g., in the case of the integers). In going from here to the analyses of pattern and structure as the order of orders, it is necessary first to study with some care a few of the problems arising when different orders are related. The simplest case of such a relationship is that of two orders impinging on each other. Consider, for example a straight road with many cars moving at the same speed, spaced at regular intervals. This would constitute an ordered pattern of movement. Consider now a second road which intersects the first. If there were a similar ordered pattern of moving cars in the second road, and if the two orders were independent, there would be a clash at the intersection. To prevent this clash, the two orders would have to be related or co-ordinated. For example, one of the drivers might stop and give way to another, by some agreed set of rules. In this way, the simple regular order on each road would be altered, and replaced by an order of groups of cars. This altered order would have the essential new property that the pattern on a given road could not be analyzed completely in terms of relationships applying in that road alone. Rather, to understand, for example, why a given group occurred on the first road, we would have to refer to some corresponding set of groups on the second roads. And this only reflects the fact that there is a larger order in the whole system, which is incompatible with a complete order in each part of aspect.

Generally speaking, then, if we consider any one road by itself, there would be an unrelatedness of different groups of cars. signalizing a lack of complete order, or as we could say, a partial and relative disorder. Such disorder can take two very distinct forms. Firstly, if the cars on each road move independently of those on the other road, then there is a clash or conflict of orders, producing a kind of disordering process, in which both orders tend to be destroyed. Secondly, if the orders are related or co-ordinated, by being aspects of a larger total order, then each aspect is incompletely ordered. In a cursory inspection, the unrelatedness of the terms in each partial aspect may seem to be similar to what could result from disorder due to a clash or conflict, but a closer study generally reveals the relationship of co-ordination, reflecting the fact that we are dealing with a partial aspect of a larger whole, rather than with a conflict of otherwise independent orders.

The typical situation that arises in physics is one in which a given partial aspect is related, not just to one or to a few other such aspects, but rather to a very large number of them. (E.g., in a large-scale system, each of the constituent atoms depends on an enormous number of similar atoms). In this case, new and rather simple characteristics can frequently arise in the statistical properties of such an array of elements. For here, it can be shown that in any partial order (e.g., of the positions and velocities of the molecules selected by a specified procedure), there is a practically complete unrelatedness of the individual elements, because each of these depends on myriads of factors that are lost to view when any one part or aspect is considered in isolation. On the other hand. as can be shown by a simple mathematical treatment (based on an analysis of what is called the "law of large numbers"), almost any one of a very wide range of possible orders in the whole leads to statistical averages over a typical selection of elements, which are practically equal to those given by the theory of probability. In this way, we obtain a clear conception of what is to be meant by the term "randomness" in cases where the theory of probability is applicable. For we see that all the results of current calculations can be comprehended through the notion that in a large aggregate, constituting a totality of related elements, the existence of certain kinds of order on the whole (e.g., a regular and simple macroscopic behaviour) entails a lack of complete relatedness in the various partial aspects, such that in a small number of these, no particular order can be guaranteed. On the other hand, when large numbers of elements are considered, there will arise corresponding statistical relationships, which are extremely insensitive to the details of the micro-order. We therefore do not regard randomness as a total absence of order, but rather, as a particular kind of order, in which there is no significant degree of relatedness between individual elements in a given group, while there are fairly definite relationships in the system as a whole.

The above discussion applies to the idealization of a completely isolated system. In our point of view, however, such an isolated system must always be considered as an abstraction from the total process of the universe. Indeed, as we have seen in the talk, each aspect of this process is connected to other aspects, both at the same level, and at different levels, by indivisible linkages that form a whole pattern and structure. For example, there must be in every theory a minimum undivided interval, which is to be taken as fundamental in that theory, while the relationships, order and structure in that theory are abstracted from the unbroken totality of lower level intervals, not explicitly taken into account in the theory in question. And in this totality, it will generally be the case that there must exist orders that, as it were "cut across" the abstraction made in any given theory and for this reason relate what is in the field treated by that theory to what is out of this field. As a result, there must be some disorder in any aspect of the universe that is subject to a relative isolation for the purposes of investigation. All orders that can be abstracted are therefore partial, limited and relative to conditions, context and degree of approximation. This means, as we have already indicated, that order and disorder cannot be absolutes; but must be like continuity and discontinuity, motion and rest, etc., merely two complementary aspects in which every phenomenon is to be studied.

Because each relatively isolable field is generally abstracted from a lower level structure-process containing a very large number of elements the disorder inherent in such a field will very often give rise to random distributions and resulting statistical regularities, which can be treated by the theory of probability in the manner already described earlier. Therefore, in our point of view, the appearance of probability in basic physical theories is to be expected as a partial reflection, within the theory, of the unbroken totality of structures on other levels and in different domains, that are necessarily left out of each kind of abstraction. In this way, we can take into account not only the probability distributions of quantum theory, but also those of statistical mechanics. For both will represent statistical regularities in the actually disordered characteristics of the structure-processes in various of the levels studied in physics. In particular, entropy can be interpreted as a certain quantitative measure of a real kind of disorder. For we now have a clear definition of disorder as a limitation on a given order due to its participation in larger relationships going outside the order in question. And the increase of entropy with time can likewise be treated without logical difficulties such as those arising in current theories, because, as we have indicated earlier, we do not begin with constituent particles and put them into interaction to make the whole system, but rather, we begin with the total process and abstract the particles. Thus, we can quite easily assume a total process which has an asymmetric structure, in which the increase with time of disorder of partial aspects associated with the entropy is built in from the outset.

Finally, it is important to go on to consider the problem of whether the totality of the universe is ordered or not. Now, we have already seen that disorder has no meaning as an absolute, but must be defined relative to some context of order. (E.g., a random sequence of coin throws has no particular relationship to the time order in which the throws are made). Vice-versa, order is generally defined against a background, that is without any particular order.

Thus, as we saw in the talk, a basic problem in modem quantum mechanical field theory is to determine the so-called "vacuum state". In terms of our point of view, this amounted to defining empty space as a structure-process that has no particular order in it. Only such a structure-process could serve as an indifferent background, which would allow every conceivable order to emerge into it, without favouring one against another. Indeed, such an indifference to particular orders is really implicit in our mode of thinking of empty space as the potential locus of all conceivable phenomena. It must be emphasized, however, that in this view, empty space cannot correspond to a structure-process that is disordered in the usual sense; since as we have seen, disorder has meaning only in relation to order. Rather, empty space reflects the quality of the totality of the universe, in that it is a kind of un-ordered matrix, containing the "germ" of all orders and disorders, just as we say that the elementary process is a-continuous, being the "germ" of both continuity and discontinuity. Our view is then that out of the un-ordered totality, various orders and structures are created, a part of which constitutes matter as we know it. These orders eventually come to clash with each other, producing disorder and breakdown of structure (i.e., de-struction). Moreover, new kinds of order and structure are continually emerging out of the unordered totality.

It is clear in the light of what has been said earlier, that a new order is very likely to be incompatible with one that is already present. The creation of what is new is therefore one side of a process, the other side of which is the destruction of what is old. We may compare the process to a flame. The flame can exist only as long as it is burning up the fuel. So the order in the molecules of fuel is being destroyed to be replaced by another order of molecules of the combustion products. The flame is what is analagous to the process itself. And the totality of universe may be regarded as such a flame, which exists by feeding on the old orders and structures, and by thus creating new orders and structures. However, let us recall that in accordance with what we have suggested earlier, existence is itself movement and process, while rest and the static are a relatively invariant aspect of this movement. To improve the analogy, we must therefore imagine, if we can, that both fuel and combustion products are aspects of the flame, in such a way that the latter can serve as new fuel when the forme r is used up, so that the process as a whole has no limits and is never exhausted. It is just this view that corresponds to the mathematical theory, the basis of which we have sketched in the talk, and which, it is hoped, can be developed sufficiently for publication in the near future.