Kenneth G. Denbigh

TIME AND CHANCE

That there is something unsatisfying about the scientific concept of nature has for long been recognized, and not least by scientists themselves. Of course there have been some remarkable changes in the foundations of science during the present century, and these have lessened the previously 'mechanistic' character of scientific theory; but it still remains true that physical science finds no place in its scheme of things for life and consciousness. "The ancients," wrote Paul Valéry, "set their philosophy to peopling the universe as ardently as we, in our time, have set ours to emptying it of all life." And similarly A.N. Whitehead [1] has spoken of the opening up, since Descartes, of a deep division between two distinct and incompatible attitudes of mind; we seek to believe simultaneously in the mechanical theory of nature and in the self-determining or creative character of living things. Hence there is a radical inconsistency, he says, at the basis of modern thought.

Within the scope of a short article[2] my aim is no more than to offer a few remarks, from my own position as a scientist, concerning certain tacit assumptions in science—assumptions, that is to say, which have been largely unconscious. "Research," said Émile Meyerson, "is always dominated by preconceived

[1] A.N. Whitehead, *Science and The Modern World*, p. 94, Cambridge, 1932; *Nature and Life*, p. 56, Cambridge, 1934.

[2] These issues are dealt with more fully in my book, *An Inventive Universe*, Hutchinson, 1975.

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ideas..." This is a viewpoint which is now widely accepted and indeed it is recognized that what Gerald Holton [3] calls 'themata' play an important part in the foundations of scientific theory.

One such presupposition, very deep-rooted in science, is that *the natural order must be thought of as being passive and inert and having no initiating powers of its own.* This of course is a world-view which had already been adopted in the 17th century, the time of Galileo and Newton, and it may well have been derived from theology. For it was a consequence of the powerful and pervasive influence of theological and scholastic doctrine that certain far-reaching but extraneous assumptions became assimilated into the metaphysical foundations of modern science during its most formative period. And no doubt one of the most significant of these assumptions concerned the notion of a transcendental Deity, one who had created and still ruled the world *as if from outside.* This was to endow the universe with no intrinsic efficacy; nothing which was genuinely novel could ever be produced by the world on its own account. For apart from further acts of Divine intervention, everything was already there in essence at The Beginning and "... there is no new thing under the sun."

Theology had thus provided an authoritative basis for the idea that all phenomena are regular and lawlike, that the universe proceeds on its way entirely fixedly. This, of course, was very helpful to science during its early period. It gave confidence to scientists that there were natural 'laws' to be discovered and it led on to that general theoretical account of nature which has become known as 'mechanism'. The idea that God had imprinted certain henceforth changeless characteristics on the world at its creation has its clear counterpart in the mechanical notions of conservation laws, temporal invariance and causality.

But perhaps it would be wrong to suggest that theological doctrine was the original influence, for the various forms of religious belief must, in themselves, have been greatly effected by man's age-long practical experience as a craftsman. No doubt it was a self-evident fact to *homo faber*, although one which was perhaps never consciously formulated, that all his tools and utensils *had to be made.* That is to say, they did not make

[3] Gerald Holton, "The Mainsprings of Discovery," *Encounter*, April 1974.

themselves spontaneously but had to be fashioned through the sweat of man's brow. It would thus have been natural for the idea to have been latent, at an early stage of man's history, that the concept of 'making' always implies an external cause or agent;[4] the world could not be self-generative but had to have a Maker: "All things were made by him, and without him was not anything made that was made." And man's practical experience may also have included what appeared as a further self-evident fact—that his tools and utensils could not be made *ex nihilo*, out of nothingness, but only out of other entities which pre-existed. If so, this may well have been the real origin of that general idea which has played such a profound role in Western science and philosophy—the idea that permanence is much more fundamental than change, that change is a mere 'appearance' and that the most fundamental entities must necessarily remain constant and self-identical. Indeed in the Scholastic maxim *ex nihilo nihil fit* the scientific conservation laws are already prefigured; and in that other maxim *causa aequat effectum*, which asserts a different sort of constancy, there is clearly stated the proposition that there can never occur any genuine novelty.

THE PASSAGE OF TIME

This presupposition of an inert and passive universe led on to two much more definitely scientific doctrines, both of them still very influential. The first, which perhaps makes the stronger claim of the two, is to the effect that there is no real ongoing of time—the time coordinate is fully symmetric and its apparent 'forward' direction is no more than an illusion of consciousness. The other is the much more familiar notion of determinism where it is assumed that every event, including all human actions, is rigorously 'caused' by the physical circumstances.

It is these two hypotheses, far more than reductionism or any others in science, which serve to alienate life and mind from the scientific concept of nature. Let us look at them more closely.

[4] Anatol Rapoport has similarly remarked that the dualism of 'mind' and 'matter'—the tendency to regard 'mind' as a substantive set over against 'matter'—may have originated with the long-established requirement of European languages for every action to be attributed to an agent. (*Theories of the Mind*, ed. J.M. Scher, Glencoe Ill., Free Press, 1962).

In personal experience there is an obvious difference between what is 'past' and what is 'future'. Past events have the characteristics of being knowable but no longer of being influenced; the past, we say, 'has already happened'. Future events appear as having the opposite characteristics; they are not fully knowable 'in advance' and they can be influenced; the future, in human experience, 'has not yet happened'.

It is this familiar concept of time which appears to be denied by science. 'The present' is not known to physics, and neither is 'past' or 'future'. Or putting it another way, all three regions of time, as they are to consciousness, are regarded by scientific theory as being equally real and having precisely the same ontological status; they belong to the same continuous time dimension and science itself, without availing itself of 'subjective' impressions, offers no means of distinguishing between them. Therefore they are regarded as being irrelevant and superfluous, however large a part they may play in everyday life. Furthermore the most fundamental theories make no distinction between 'time forward' and 'time backward'—the two directions along the time dimension are taken as being fully equivalent. A sequence of events, according to these theories, might just as well be regarded as 'taking place' in the anti-sequence, like seeing things in a film projected in reverse. Thus, as well as not distinguishing between past, present and future, fundamental science offers no rule from within itself whereby any one event could be said to take place 'earlier than' (or 'before') another event.

Perhaps it should be added that the notion of *evolution* remains meaningful, although in a limited sense. Science deals, of course, with the evolution of the galaxies and stars, of the solar system and of life on earth. But this it does by means of a 'boundary condition', and the reverse boundary condition, which would lead to an anti-evolution, remains, so to say, entirely thinkable. This is because any boundary condition which is used in solving the theoretical equations in a given practical situation is regarded as *de facto* and is therefore extraneous to the nomological content of the equations. Originally it was the immense success of Newton's time-reversible mechanics which caused the notion of a fully symmetric time to become so firmly entrenched in physical theory. Relativity and quantum theory continue to use the notion of a time coordinate which has no unique direction and which offers no distinction, other than is provided by an 'observer', between past, present and future.

This notion of static time, equivalent to the assumption of a 'block universe' as William James called it, is obviously very deeply opposed to the temporality we associate with the living. Mental activity is the succession of one thought after another, and purposiveness too implies a real ongoing of time. Life, as it appears to itself, is an active search and is creative. Yet to many scientists and philosophers who accept the notion of a block universe, the apparent 'happening' of events is no more than a peculiarity of consciousness. What they claim is that consciousness is such that we experience a succession of 'nows' or 'presents' during which we merely 'come across' the events which are already laid out, in a sort of timeless sense, within the space-time manifold.[5] C.D. Broad has used the analogy of a policeman's torch which can be used on a dark night to bring one house after another as if 'into existence', although the houses are already there.

However the question needs to be asked whether the physical theories actually *necessitate* temporal symmetry—i.e. in the sense of logical entailment. This requires the matter to be explained rather more technically than hitherto. The significant point is that the mathematical equations of Newtonian mechanics, as well as of all later physical theories, allow of the time variable $+t$ always being replaceable by $-t$. This means that for every phenomenon which is permissible and explicable according to these theories, the temporal reverse of that phenomenon is equally permissible and explicable. And of course there are many important instances where the equations in question provide a good, or even a very precise, approximation to what can be observed experimentally. The classic example is that of the frictionless motion of the stars and planets, as dealt with in Newtonian mechanics, but many other more recent examples from the field of atomic phenomena might be quoted. Since the theories have had such an impressive record of success, when they were applied where they do apply, it was perhaps not unnatural for the assumption to be formed that the replaceability of $+t$ by $-t$ meant that time is

[5] Several presentations of this concept have used a question-begging terminology. What I believe is the most rigorous presentation is that of Adolph Grünbaum, *Philosophical Problems of Space and Time*, Ch. 8 and 9, New York, Knopf, 1963.

indeed directionless. Henry Mehlberg, one of the most forthright proponents of this viewpoint, has drawn the conclusion: "...on presently available scientific evidence time should be considered as having no arrow or unique direction,.. the only plausible way of accounting for the fact that so many well-established and comprehensive laws of nature somehow conceal time's arrow from us is simply to admit that there is nothing to conceal. Time has no arrow."[6]

However this is by no means a necessary conclusion. In the passage quoted I feel that Mehlberg should have spoken of "theories" in place of "laws of nature." It is the various theories, such as Newtonian mechanics and relativity and quantum mechanics, which have been formulated in such a way as not to require the notion of time's arrow. But these theories are in no respect fiats; and neither do they logically exclude the possibility of a non-symmetrical time. For the mere fact that these theories can manage with a sort of pared down time-concept, one which does not include an important aspect of temporal experience, does not mean that this aspect is unreal; it means no more than that it is not made use of in these particular theories.

And indeed within inanimate nature, as well as in the phenomenology of conscious experience, there is an important group of processes which are not at all readily explicable on the basis of temporal symmetry. These are processes which are very familiar in everyday life; for instance the spontaneous mixing of gases or liquids; the equalization of temperatures between hot and cold bodies in contact; the combustion of fuels, and so on. We never observe *the reverse* of these processes; when tea and milk have mixed with each other they are never found to *unmix* and when an ice cube has melted in a glass of tepid water it does not reform itself spontaneously. No doubt these are glimpses of the obvious, but the important point is that nature offers almost innumerable examples of irreversible or 'one-way' changes whose character appears as being quite at variance with the reversible changes which are postulated in the fundamental theories. When their common features are extracted they lead to the well-known Second Law of Thermodynamics[7] which expresses the existence of

[6] H. Mehlberg in *Current Issues in the Philosophy of Science*, ed. H. Feigl and G. Maxwell, Holt, Rinehart and Winston, New York, 1961.

[7] It may be remarked that in this instance we are dealing with a 'law'

a non-conserved quantity, entropy. The nub of the matter is that all entropy changes are found to occur *in parallel*; that is to say, the various irreversible processes display increasing entropy (which is thus literally created) in the one direction along the time coordinate, and the same processes display decreasing entropy (literally annihilation) in the reverse direction of time. It is probably far from being an accident that it is the direction of increasing entropy which coincides with the human sense of 'time's arrow'.[8]

The Second Law may thus be said to be the only 'law' of nature so far known[9] which lends support to the conviction we have from consciousness that temporal processes are 'one-way only'. Indeed the law has sometimes been spoken of as being irrational—irrational, that is to say, when looked at from the standpoint of the time-reversible theories and not, of course, from the standpoint of conscious awareness. For this reason many scientists, such as Max Born and Schrödinger, have given immense intellectual effort to the attempt to explain how large-scale irreversibility might be accounted for on the basis of the reversible motions which are supposed to occur at the atomic level.

To discuss this matter in any detail would be out of place. Suffice it to say that a 'boundary condition' has to be invoked, over and above the content of the theories. The assumption is made that the universe, in some sense, had a 'beginning condition' (although from the standpoint of the theories in question, this could equally well be thought of as an 'ending condition'). The occurrence of irreversible processes is then interpreted statistically as representing the approach towards a state of the universe which has greater randomness or disorder. The irreversible phenomena are therefore seen as being similar in character to

far more than with a theory. The Second Law of Thermodynamics does not require an idealization, an abstraction from the actual state-of-affairs, to anything like the same extent as the various theories.

[8] Rather convincing arguments can be brought forward to the effect that life, and hence the possibility of observation, would be impossible under the conditions of a reserved world where there would be diminishing entropy.

[9] Nevertheless there are other natural phenomena, such as the outward movement of radiation from a source and the supposed expansion of the universe as a whole, which also support the idea of temporal asymmetry. The relationship of the thermodynamic, the electromagnetic and the cosmological 'arrows of time' has not yet been properly cleared up and is one of the outstanding scientific problems awaiting solution.

the shuffling of a pack of cards; an 'initial' state in which the cards are in the arrangement A,K,Q etc. gives way to one in which they are in no particular sequence. This means that the whole burden of reconciling the Second Law with the time-reversible theories is transferred to the existence of a boundary condition which in itself is of the nature of a miracle.[10] And the miracle, as Eddington expressed the matter, is put at 'the beginning' of time and not at 'the end'.

As against all such attempts to 'reduce' the Second Law Meyerson made the important point that this law "is a fact, and by far the most important fact of all science. Indeed it is enough to regard reality without prejudice to be convinced that that which is permanent is but little compared with that which is changing."[11] It is a law, he said, which "reinstates reality."

Here is expressed the important difference between abstraction and concrete experience. For many scientific purposes it is a helpful abstraction to regard the world as consisting of lumps of matter which move about reversibly in a spatio-temporal continuum. There is also a certain aesthetic attraction, especially to the theoretician, in the attribution to time, and indeed to everything else, of the maximum of symmetry. Yet none of the theories of science would need to be altered if they were to operate with the much richer asymmetrical time-concept which we obtain from conscious experience; for no inconsistency whatsoever is involved in maintaining that the replacement of $+t$ by $-t$, though permissible in physical theory, does not correspond to a real operation in the world-as-it-is.

HOW RIGID IS 'CAUSALITY'?

The other doctrine which was mentioned as arising from the presupposition of a passive universe is that of a rigid causality. The Scholastics expressed this in memorable phrases such as

[10] There are other theories which suppose that the universe oscillates eternally between one such boundary condition and its converse. Yet these are theories which, in my view, do not indicate at all satisfactorily how a meaningful time direction could be assigned such that a supposed 'reverse phase' of the universe would be deemed as being indeed a reverse phase.

[11] E. Meyerson, *Identité et Realité.* English edition, *Identity and Reality,* transl. K. Loewenberg, London, Allen and Unwin, 1930.

causa aequat effectum and "every event is already present in its causes." Yet it was Laplace who carried determinism to its logical conclusion. This was his celebrated claim that a sufficiently powerful intelligence, having a knowledge of all the forces of nature together with a knowledge of the instantaneous state of every atom, could predict the universe's entire future and retrodict its entire past.

Determinism, in spite of some serious doubts which have arisen due to the advent of quantum theory, continues to be attractive to many scientists for a metaphysical reason. Determinism gives grounds for the faith that scientific laws should be discoverable which will be true in *all* instances, and not merely as the result of averaging. Einstein expressed the faith of many scientists in strict causality when he said he did not believe that God plays dice with the world.

Yet Einstein would probably have agreed that neither determinism nor its converse are very clear propositions. Indeed one of the major problems is to express the general idea in a form which would be capable either of being falsified or of achieving some degree of corroboration. One of the more down-to-earth versions runs as follows: "If a state A of a system not subject to interference from outside is followed by state B, that same state A will always be followed by state B." This might seem to express the notion of rigid causality in a form such that any counterexample, if it were ever observed, would suffice to falsify it. Yet it is essentially a circular statement! For a system cannot, in fact, be shown to be free from external interference without already assuming the truth of the statement, and neither can it be shown that a second apparent repetition of the states A and B is indeed an exact repetition without once again assuming that the statement is true.

This may be illustrated by an example due to Philipp Frank: two bars of iron lie on a table and they remain motionless; thus the state A is here followed by the same state; but on a second occasion the two bars of iron swing round and slide towards each other. Does this not falsify the whole notion of precise causality? Not at all, according to physics, for it is supposed that on the second occasion the bars are *not* in the same initial state A as on the first. They are now endowed with the imperceptible property known as magnetization. Yet the history of this property is that it was invoked in the first place, from the time of William Gilbert onwards, precisely in order to 'save' the notion of determinism in just such experiments! As Frank puts it "...the task of theoretical science is to provide bodies with fictitious properties the chief purpose of which is to insure the validity of the law of causality..." Which is not to say, of course, that science is not generally very successful in the theoretical scheme which it develops. That is not my point here; my point is that the notion of determinism has played the role of a self-fulfilling prophecy.

Yet another formulation which has been put forward is to the effect that "everything in the world occurs according to laws." Yet this proves to be equally a will-o'-the-wisp as regards testability. For suppose one discovered an apparent counter-example—i.e. an event which was not accountable for by physical laws. It could always be said that this was because the requisite laws had not yet been brought to light, or because the data required for applying the laws had not yet been obtained with sufficient precision. Thus one would again be concerned with a circular situation—one in which an apparently non-lawlike event, *together with the assumed truth of the causality statement*, was used as evidence that either new or better laws, or better data, remained to be discovered. One would be invoking the unknown in order to 'save' the statement.

Perhaps it may be said that the above is not to look at the matter sufficiently generously. It might be claimed that the notion that "everything occurs according to laws" has been given great encouragement by the immense success of Newtonian mechanics; for instance in regard to the fantastic precision with which the movement of the stars and planets can be predicted; or again the remarkable accuracy with which a space capsule can be landed on a small chosen area on the moon. As against such an argument it needs to be said however that there are at least two large groups of events or processes, not studied in Newtonian mechanics, where prediction seems impossible—and impossible, perhaps, *even in principle.*

One such group is concerned with single elementary events at the atomic level. Science knows of no means whatsoever whereby a single radium atom can be singled out and the moment of its radioactive decay be predicted. The same applies to the

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sort of events in which quanta of energy are absorbed or emitted by atomic particles. Indeed if Heisenberg's Uncertainty Principle remains a permanent feature of science (and to assume that it will eventually be replaced by a deterministic principle would be no more than a gamble) the possibility of making any precise predictions concerning atomic events is entirely precluded. This Principle leads to the conclusion that all laws of science are essentially *statistical laws* and their precision therefore depends on the number of particles over which an averaging process is carried out. The very success of Newtonian mechanics arose from the fact that the mechanics was applied to bodies of macroscopic size and thus composed of millions upon millions of elementary particles. Statistical laws can be very exact indeed when they apply to such numbers and yet without assuming that the behaviour of any single particle can be predicted with certainty.[12]

Another group of events where exact prediction is out of the question are those which are due to living organisms. How would one set about predicting the detailed actions of a particular person or even of a particular amoeba? Since each separate organism is an individual, differing in detail from all other members of its species, there can never be any specifically biological laws which would apply with certainty and perfect precision in every instance. Physicochemical laws are also of little use; to apply these laws for predictive purposes, in the manner of how they are applied to inanimate material, would require the assembly of an amount of data relating to the internal state of the individual organism which could only be obtained by completely dismembering that organism.

Thus it was perhaps in some respects fortunate, and in other respects unfortunate, that the pioneering work of Galileo and Newton, which formed the pattern for modern science, was restricted to the level of macroscopic inanimate bodies. For at the lower level of the atoms and molecules, and again at the higher level of the living organisms, the uncertainties in prediction are very much greater and the credibility of strict

[12] An analogy may be helpful to the reader at this point. Actuaries know the average expectation of life in a population of a given age with very great accuracy; yet the actual future life span of any one individual in the age group remains quite unpredictable.

determinism is correspondingly very much less. As A.J. Ayer put it: "The thesis of determinism has lived very largely on the credit of classical mechanics."

Thus, in my view, determinism is not a proposition which may be shown to be either true or false; it is rather, as Schlick has remarked, "a postulate, an injuction to continue to seek causes." Nothing that has been said above is contrary to the view that most phenomena are regular and orderly, and are capable of being explained on the basis of reasonable 'mechanisms'. Yet this does not mean that every event is rigidly determined in advance, through the action of fixed 'laws'. Looked at in this light, causality is not a hidden compulsion acting on nature; it is rather a requirement of the mind, an heuristic principle useful for purposes of theoretical understanding.

What I am thus denying is that one can speak of 'causes', as a noun-word, as if they had an objective existence set apart from the real (but usually incompletely knowable) properties of real things. Rather than regarding every event as having causes, or as not having causes, we should more correctly regard it as being either predictable or non-predictable; or better still as being predictable to a certain degree of accuracy. Indeed when we reflect on the matter, is it not apparent that at every stage of human knowledge, however far in the future, there will always remain certain events which are not predictable (and it is these which are most truly called *chance events*)? This for the simple reason that an ultimately complete description of any real thing can never be achieved. A conceptual entity, such as a triangle or an ellipse, can always be fully specified, but the same is not possible concerning objects belonging to the actual world of the senses; with these something will always be left unsaid. Because of this we can never be in a position to foresee what will happen in the future with certainty; predictions will always contain an element of contingency.

David Bohm has made a similar point with his concept of the *qualitative infinity of nature.*[13] By this he means "that nature

[13] D. Bohm, *Causality and Chance in Modern Physics*, Routledge and Kegan Paul, 1957. Although Bohm is often regarded as having aimed at establishing a new basis for determinism in science, this is not at all inconsistent with his more general philosophical outlook as described in this book.

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may have in it an infinity of different kinds of things" and may thus have an inexhaustible richness and complexity. Such a view, he points out, is in conformity with what has actually been found in physics—levels below levels below levels—and there can be no certainty that the discovery of deeper and deeper levels will ever come to an end. Also he believes that the higher level entities may never be completely explainable in terms of those at a lower level. The very notion of a 'thing' as an abstraction for its effect is to lead to a conceptual separation: "Each 'thing' existing in nature," he says, "makes some contribution to what the universe as a whole is ... And, vice versa, this also means evidently that no given thing can have a complete autonomy in its mode of being, since its basic characteristics must depend on its relationships with other things."

CREATION

If one speaks about 'creation' or about 'self-creation' this must refer to a temporal process, something taking place in time, and the process itself can be understood in at least two different senses.

The first concerns the possibility of creation *ex nihilo*, and this has always excited a strong emotional resistance since it strikes very hard at man's sense of security; for example if it were supposed that tangible objects could suddenly appear out of nothingness or disappear into nothingness. But to claim, as some philosopher and scientists have done, that creation *ex nihilo* is 'unthinkable' seems wide of the mark. The so-called Genetic Principle, *ex nihilo nihil fit*, was regarded by Mach as no more than an empty maxim and Bondi, Gold and Hoyle went so far as to develop a scientific theory of 'continuous creation'.[14] What they assumed was that just as fast as the universe expands, new matter is steadily created, thereby establishing a 'steady state' or time-invariant condition. And

[14] When one speaks of 'creation', rather than of 'annihilation', it is, of course, the time direction of consciousness which is implicitly referred to. In one of his more popular expositions of the theory, Hoyle estimates the required rate of creation as being about one atom per year in a volume equal to the interior volume of St. Paul's Cathedral.

although this particular theory has run into difficulties [15] what is nevertheless very significant is that a theory which contravened the Genetic Principle could have made a serious contribution to science. Indeed the general notion seems in many respects more rational than the alternative assumption of an inexplicable boundary condition at 'zero time'.

There would, of course, be immense difficulties in the way of abandoning conservation principles in science. The notion of continuants or temporal invariants has been deep-rooted in scientific thought ever since Democritus and it cannot lightly be discarded. It may be suggested nevertheless that if a theory which regards the universe as being self-generative were to be developed successfully, such a concept would surely be no more mysterious, and perhaps less so, than is the traditional assumption—the legacy from theology to science—that everything came into existence once and for all.

In what follows however it is the other sense of 'creation' I shall be dealing with and this concerns the occurrence of novelty. Here it is no longer a question of contravening the Genetic Principle, or any of the conservation laws, but only the dictum *causa aequat effectum.*

Let us speak about an *inventive process* as that which gives rise to something which is novel. The absence of causal necessity is an essential requirement for the occurrence of such processes since one could not regard anything as being genuinely novel unless it were both different from, and not necessitated by, anything previously existing. It is just this possibility which arises if, as I have argued, there is a real temporal ongoing and if the doctrine of determinism is gratuitous.

Think of the various 'levels' within the natural order. A useful and commonly adopted scheme is as follows:

L_6 Social groups
L_5 Multi-cellular organisms
L_4 Cells
L_3 Molecules
L_2 Atoms
L_1 'Fundamental' particles

[15] Relative to the competing 'big bang' theory which effectively assumes a beginning of the universe.

The point I want to make is that science provides no principles or laws by which it could be predicted with certainty that some yet higher level, L_7, will make its appearance in the future. To be sure one might suggest the emergence of L_7 as a speculation, in the manner of science fiction, but that would be very far from amounting to a deduction, something which followed of necessity. Yet similarly, I suggest, in regard to the relationship between most of the lower levels, L_1 to L_6. An 'intelligence' knowing only of the existence of, say, molecules could not have predicted with certainty that cells would be formed, nor if he had known of the existence of cells could he have predicted the formation, or the particular characteristics, of multi-cellular organisms; and neither could he have deduced the distinctive features of their social groups. Thus to the extent that the levels listed above do, in fact, correspond to a temporal sequence, as well as to a sequence of ascending levels of organization, it seems likely that several, if not all, of the transitions between these levels correspond to what I have called an inventive process.

CHANCE

If one considers what is involved in these transitions in greater detail one can hardly fail to be impressed by the importance of chance; 'mere' chance, as we tend to say; chance as the antithesis of predictability. Yet that is not the whole story, for the higher the level the more significant, as further components of an inventive process, are stages of selection and amplification.

Take, for instance, the chemical basis of evolution as it is at present understood. This involves a chance event, a mutation, such as may occur when a high energy quantum of radiation impinges on the sensitive part of a gene. If the DNA molecule, as the result of this impact, undergoes some change in its structure this means that the 'message' which this molecule is capable of transmitting is thereby altered. Selection and amplification then come into play in a two-fold sequence. The compatibility of the changed message with the existing chemistry

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of the cell is first tested out, and, if compatibility is attained, this means in effect that a slightly altered but still viable cell has been produced by a process of internal selection and amplification. In other words the cell now has a somewhat altered 'life strategy' and this is tested out in a second stage in which the cell has to compete with its unchanged fellows for the available nutrients. If it is not quickly extinguished in this competition, which is to say if it proves successful in Darwinian selection (selection by the environment), it becomes the prototype for a second amplification process—i.e. that which consists in its own reproduction to form a whole population of altered cells.

In short it is the chance effects [16] which provide the organism, so to speak, with a set of possible futures; and it is the processes of selection and amplification which enable the organism to seize hold of the 'merely' chance effects in a creative manner, thus resulting in richness and diversity. It is a truism that nature displays a progressively more and more inventive character the higher the level in the evolutionary sequence and the more definitely the organisms at that particular level may be said to have consciousness and mind. In a recent book A.R. Peacocke has expressed the point very clearly: "Of what sort of 'material'," he asks, "is the universe constituted if in the course of time it becomes organized to form the brain of a man, the creative thought of a Newton, a Beethoven or a Shakespeare, the person of Buddha or of Jesus of Nazareth?" The evolution of man, he says, "demonstrates the ability of matter to display properties which we normally, in talking about this human level of matter call mental, personal or spiritual."

This brings me back to my point of departure, the exclusion of life and consciousness from the scientific concept of nature. Science and ethics obviously adopt very different viewpoints; science leans towards determinism and ethics towards free-will, and this large difference of emphasis is an important feature of the matter at issue. Yet to argue, as I have done, that determinism has little empirical support is by no means to answer any

[16] Although chance is essential, too much would be harmful. The life processes must surely require an optimum point of balance between necessity and chance, between order and disorder, and this is discussed more fully in my book *An Inventive Universe.*

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questions concerning free-will. For it is *chance* which is the opposite concept to that of determinism,[17] whilst 'free-will' belongs to a radically different area of discourse.

Whilst remaining within the naturalistic area, consider what sort of act is involved when a living creature is said to make an act of selection. What does 'selection' really amount to? As has been said already, determinism cannot be shown, in relation to the real world, to be either true or false. But of course it can still be entertained as a proposition, metaphysical and untestable though it is, and as such must either be true or its negation must be true. Our ordinary two-valued logic allows of no third possibility. Thus from a logical standpoint it would appear that acts of selection must be regarded either as being fully determined or as occurring by chance.

When faced with these alternatives my own preference is to opt for chance. The notion of chance is held in altogether too poor esteem in science and philosophy. Of course it means a denial of the completely lawbound—but indeed why not? It is a very narrow conception of what is rational to suppose that everything must occur according to natural 'laws', for these are made by man and not by nature. It is far more realistic, I suggest, to give value to the idea of chance and regard it as the origin of everything that is new and inventive.

Yet the question about determinism being either true or false has perhaps presented natural philosophy with a quite unnecessary strait-jacket. The real issue, metaphysical propositions apart, concerns predictability, and, when the matter is looked at in this light, there are good reasons for thinking that nature usually provides us with a sort of *mixed* situation—one in which there are simultaneously a number of factors which tend towards a predictable outcome of a future occasion and a number of other factors which tend towards an unpredictable outcome. To postulate a mixture of orderliness and disorderliness in this kind of sense is by no means to throw the doors wide open to the denial of any lawlike phenomena whatsoever. It is rather to adopt

[17] I am speaking here of what C.S. Peirce and William Kneale have called 'absolute chance' as meaning the negation of determinism. But of course one can also speak of a chance event in a much weaker sense as meaning a type of event which cannot be accounted for causally in one particular context, but may be so accounted for in a different and more appropriate context.

the usage that any event may be said to be partially determined and partially undetermined and it is also to suppose that all scientific laws are essentially *statistical* laws—as is indeed now widely accepted in science.

I began by quoting Whitehead's remark about the deep division in Western thought, the division between nature and life as he put it (and of course by 'nature' he meant as portrayed by physics.) I want to end by pointing out that a remedy is available from within science itself, although it is one which has not yet been made good use of.

The remedy lies in a hypothesis which is widely accepted among scientists, the hypothesis of the unity and continuity of nature. Its meaning can best be illustrated by going back to the various 'levels' as previously described, for what is asserted is that there is a real continuity between these levels and that eventually they should be capable of being brought together within the scope of a single unifying theory. That is to say, there should be the possibility of a unitary conception of nature. The same hypothesis therefore denies that there is the need for any special principles to be brought in at one group of levels if these principles are entirely inoperative at another group. A notion such as vitalism, which supposes that some vital force or entelechy serves to distinguish the realms of the living and the non-living (if indeed there can be any such distinction) should therefore be ruled out.

As has been said, this idea that nature is 'all of a piece' is widely accepted, but it tends to be applied in only one direction. By this I mean that it is applied 'upwards from the bottom' whereby the phenomena of living things are explained in terms of the phenomena of atoms and molecules; *but it is not also applied in reverse.* Of course 'reductionism' has had some wonderful successes; perhaps the best known is the partial elucidation of heredity from a knowledge of the structure of the DNA molecule, the famous 'double helix'. But let us ask why this fertile hypothesis of continuity has not also been applied in the reverse direction. The reason for applying it only in the reductionist sense, or so it has been said, is that atoms and molecules are far more prevalent in the universe than are living organisms. Physics therefore provides a much more comprehensive system of explanation than do any of the biological sciences. As

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Oppenheim and Putnam[18] expressed the matter: "One supposes that psychology may be reducible to physics, but not that physics may be reducible to psychology." Without denying the strength of this argument, justice needs to be done to the simultaneous value of the converse procedure of working 'downwards from the top'. Or putting it more correctly, the value of applying the continuity hypothesis in *both* directions.

Even to contemplate applying it in the downwards sense would be regarded by many scientists as being highly suspect. But surely without good reason and only because of a long-standing scientific tradition. There is a real weakness in reductionism pure and simple and this is its tendency to ignore those sorts of phenomena which are readily observable only at the level of the living organism and not at all at the level of the atoms and molecules. These, of course are pre-eminently the phenomena of sentience, consciousness and mind. No doubt the pure reductionist wishes these phenomena out of existence. Yet this would do violence to the whole of our general understanding. Sentience is not a concept we can do without, and its reality has to be accepted as a fact, however rare a thing life may be in the universe.[19] Therefore the hypothesis of the unity and continuity of nature requires us to think of sentience as being present below the lowest level which is conventionally regarded as consisting of living things, even though this attribution of sentience must naturally be in a very attenuated form. Sentience must indeed be thought of, according to the logic of continuity, as being in some sense latent even at the level of the fundamental particles; but of course not in the sense of determining the character of the higher levels; only in the sense of providing a possibility.

Whitehead, in his *Science and The Modern World*, has quoted an interesting passage from Francis Bacon: "all bodies whatsoever, though they have no sense, yet they have perception." By 'perception' Bacon is to be understood, says Whitehead, as meaning 'taking account of', as is instanced by the power of bodies to respond to hot and cold, to be attracted or repelled by

[18] P. Oppenheim and H. Putnam, *Minnesota Studies in the Philosophy of Science*, Volume II, University of Minnesota, 1958.

[19] As is well known there are certain grounds for thinking that life may be not at all rare, and indeed that there may be intelligent beings elsewhere in the Milky Way. But this is still entirely speculative.

each other, and so on. Whitehead goes on to say: "in this respect Bacon is outside the physical line of thought which finally dominated the century. Later on, people thought of passive matter which was operated on externally by forces. I believe Bacon's line of thought to have expressed a more fundamental truth than do the materialistic concepts which were then being shaped as adequate for physics."

No doubt it was the very success of quantitative physics and chemistry, in the relatively simple domains which are their own, which persuaded later developing sciences, such as biology and psychology, to adopt a conceptual scheme which was not of their own making and not fully congenial to their own subject matter and outlook. To take better account of life may therefore require certain changes in the conceptual foundations of science and these might be attained, as in Whitehead's own metaphysics, by using some of the notions of panpsychism. For although one may look at the natural order from below and find it emptied of all life (in Valéry's phrase), one must also look at the natural order from above, from man's own position, and here the sense of the animate, together with value and purpose, becomes entirely dominant. And even if Whitehead's system in itself is not entirely acceptable there remains an important programme for science and philosophy which is to achieve a linking up of the notions appropriate to physics and chemistry with the notions appropriate to biology and psychology. My own view, which I have been able to indicate only in outline, is that we must seize hold of those particular concepts such as time and chance, used throughout the whole range of the sciences, where the presence of a distinctively mentalistic, or even subjective, component is most in evidence, and build on these.

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