Chance and the Laws of Nature

by Noel Roberts

The notion of 'chance' as a cause of the universe has fascinated many minds and nearly always it has been associated with its primeval beginnings. Milton, in *Paradise Lost,* especially Book II, line 890, et seq., paints a picture of the primeval chaos across which Satan is about to begin his journey from Hell to seek out Man and his earthly paradise.

> 'Before their eyes in sudden view appear
> The secrets of the hoary deep, a dark
> Illimitable ocean without bound,
> Without dimension; where length, breadth and highth,
> And time and place are lost; where eldest Night
> And Chaos, ancestors of Nature, hold
> Eternal anarchy, amidst the noise
> Of endless wars, and by confusion stand.
> For Hot, Cold, Moist, and Dry, four champions fierce,
> Strive here for mast'ry, and to battle bring
> Their embryon atoms; they around the flag
> Of each his faction, in their several clans,
> Light-armed or heavy, sharp, smooth, swift or slow,
> Swarm populous, unnumbered as the sands
> Of Barca or Cyrene's torrid soil,
> Levied to side with warring winds, and poise
> Their lighter wings. To whom these most adhere,
> He rules a moment; Chaos umpire sits,
> And by decision more embroils the fray
> By which he reigns; next him high arbiter
> *Chance* governs all.

Milton's poetic imagery is borrowed in large part from the Ancient Greek thinkers Empedocles, Leucippus, Democritus and Epicurus.

In early Greek philosophy two principles or causes were seen to operate through matter, 'necessity' (*ananke*) which gradually lost its religious sense to become something akin to our 'natural law', and 'chance' (*tyche*) something originally divine and mysterious which eventually took on the meaning of some random or acausal principle in matter. Aristotle in his Physics Book II refers to those who hold chance to be a cause:

> 'Some moreover hold that chance is a genuine cause of things, but one that has something divine and mysterious about it, that makes it inscrutable to the human intelligence'.

So deeply rooted in man is this notion of chance that over the ages philosophers and scientists have postulated the existence of absolute

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'chance' as a cause of phenomena either to prove or disprove the existence of a creator, an all-powerful inscrutable being. I say postulate, because by the very nature of the postulate it can never be proved. For to show that a given happening is spontaneous and without predetermining conditions, i.e. due to absolute chance, it would be necessary to show that there is nothing whatever upon which its occurrence depends—an impossibility in practice.

Philosophers as far apart in time (but not in thought) as Epicurus, 4th-3rd century B.C., in Greece and Charles Peirce the American philosopher and scientist, 1839-1914, have postulated absolute 'chance' as a cause of *some* events in the universe. Both of them had an abhorrence of a universe governed by immutable laws of nature which stemmed from an instinctive distrust of a rigid determinism. Instead of seeing a universe governed by well-defined laws as a magnificent and delicate piece of workmanship, they viewed it as a lifeless mechanism with no provision for the spontaneous and the unexpected which we associate with nature. Surprisingly both of them were intensely aware of the spontaneous nature of human thought and saw it as a proof of the existence of the spontaneous and the uncaused, i.e. absolute chance. Peirce expresses these sentiments at some length in his article 'The Doctrine of Necessity'.

> 'Necessitarianism cannot logically stop short of making the whole action of the mind a part of the physical universe. Our notion that we decide what we are going to do, if as the necessitarian says, it has been calculable since the earliest times, is reduced to illusion. Indeed, consciousness in general thus becomes a mere illusory aspect of a material system. What we call red, green, and violet are in reality only different rates of vibration. The sole reality is the distribution of qualities of matter in space and time. Brain-matter is protoplasm in a certain degree and kind of complication—a certain arrangement of mechanical particles. Its feeling is but an inward aspect, a phantom. For, from the positions and velocities of the particles at any one instant, and the knowledge of the immutable forces, the positions at all other times are calculable; so that the universe of space, time and matter is a rounded system uninterfered with from elsewhere. But from the state of feeling at any instant, there is no reason to suppose the states of feeling at all other instants are thus exactly calculable; so that feeling is, as I said, a mere fragmentary and illusive aspect of the universe. This is the way, then, that necessitarianism has to make up its accounts. It enters consciousness under the head of sundries, as a forgotten trifle; its scheme of the universe would be more satisfactory if this little fact could be dropped out of sight. On the other hand, by supposing the rigid exactitude of causation to yield, I care not how little—be it but by a strictly infinitesimal amount—we gain room to insert mind into our scheme, and to put it into the place where it is needed,

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into the position which, as the sole self-intelligible thing, it is entitled to occupy, that of the fountain of existence; and in so doing we resolve the problem of the connection of soul and body.'

Epicurus as early as the 4th-3rd century B.C. also was very much aware of the unpredictability of human thought and sought the reason at the level of the primeval seeds or atoms of the universe. His physical picture of the origin of absolute chance, I feel, makes his argument somewhat less convincing.

In the poem, *De Rerum Natura* by Lucretius, the zealous disciple of Epicurus, we have several descriptions of the most primitive 'chance' event, the *parenklisis* or the 'swerve' of the falling atoms which results in fruitful collisions between them and the subsequent growth in complexity until the primeval 'swerve' manifests itself at the level of the human mind in a radically different form, 'free will'.

> 'When atoms are travelling straight down through empty space by their own weight at quite indeterminate times and places they swerve ever so little from their course' (Lucretius II. 217-219).

And again

> 'If all movement is always connected, the new arising from the old in a determinate order—if the atoms never swerve so as to originate some new movement that will snap the bonds of fate, the everlasting sequence of cause and effect—what is the source of the free will (voluntas) possessed by living things throughout the earth? What, I repeat, is the source of that will power snatched from the fates, whereby we follow the path along which we are severally led by pleasure, swerving from our course at no set time or place but at the bidding of our own hearts?' (Lucretius II. 251-260).

Presented in this physical manner the 'swerve' seems to merit the condemnation of Cicero as 'a puerile invention'. (Although it is in keeping with the findings of modern physics concerning sub-atomic particles.) Nonetheless, it was an effort to provide a physical basis for his intuitive recognition of spontaneity in the human mind. He chose the materials at hand, the atomic theory of Democritus, and modified it subtly by the introduction of the 'swerve' to give his argument much needed support. Epicurus and Peirce recognised the spontaneous nature of human thought processes and showed that they had the character of absolute chance events.

The rise of experimental science in the 16th century, especially the science of mechanics, culminating in the synthesis of Isaac Newton, engendered in the minds of many a picture of the universe in which all bodies moved according to certain fixed laws of Nature. In fact the deterministic aspect of nature was so stressed from the time of the initial success of Galileo to the complete synthesis of Newton that Laplace felt confident in expressing the following view in 1820 (*Théorie Analytique des Probabilités*).

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> 'We ought to regard the present state of the universe as the effect of its antecedent state and as the cause of the state that is to follow. An intelligence knowing all the forces acting in nature at a given instant, as well as the momentary positions of all things in the universe, would be able to comprehend in one single formula the motions of the largest bodies as of the lightest atoms in the world; provided that its intellect were sufficiently powerful to subject all data to analysis, to it nothing would be uncertain, the future as well as the past would be present to its eyes. The perfection that the human mind has been able to give to astronomy affords a feeble outline of such an intelligence. Discoveries in mechanics and geometry, coupled with those in universal gravitation, have brought the mind within reach of comprehending in the same analytical formula the past and the future state of the system of the world. All the mind's efforts in the search for truth tend to approximate to the intelligence we have just imagined, although it will forever remain infinitely remote from such an intelligence'.

Not until the failure of classical physics to describe the behaviour of sub-atomic particles did this impressive edifice begin to totter. Signs of collapse had appeared earlier in the development of the kinetic theory of gases. The theory, which was given precise mathematical expression by J. Clerk-Maxwell (1860) and L. Boltzmann (1868) supposed a gas consists of a large number of very small, perfectly elastic particles moving in a completely random fashion. Since all the particles can not have the same velocity because of impacts with other particles only the distribution of velocities is held to be constant. No attempt is made, in fact no attempt could be made, to determine the velocity and position of individual particles at any instant. The analysis is based on the theory of probability of a very large number of particles with a constant distribution of velocities at any one temperature. The state of the system of particles is taken as that having the *maximum probability*. The impressive agreement with the laws governing the behaviour of gases profoundly affected our way of thinking about matter. As the Thomistic philosopher, Yves Simon, remarks in his book *The Great Dialogue of Nature and Space*:

> 'Many thinkers have judged that this integration of chance in law constituted the most radical of all the revolutions ever undergone by the scientific mind and marked the definitive invalidation of the regulating ideal that science received from Greek rationalism'.

We must beware, however, of equating the relative chance of the kinetic theory with absolute chance. In the kinetic theory it is explicitly asserted that we are dealing with random events which can only be grasped statistically. No claim is made that these events are acausal or due to absolute chance.

On the other hand, the development of wave or quantum mechanics

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by W. Heisenberg (1925) and E. Schrödinger (1926) to account for the behaviour of sub-atomic particles has been taken by many to mean that the statistical state description of the particles reflects the inherently undetermined or absolutely chance nature of sub-atomic processes. However, the theory is compatible with either relative or absolute chance, i.e. the processes may or may not have pre-determining conditions. If they do have pre-determining conditions they are as yet unknown and the best we can do is to treat them statistically. Albert Einstein was a proponent of the deterministic view while a large number of scientists favour the view that sub-atomic processes are purely fortuitous. However, as remarked at the beginning of this article, such a statement by its very nature could never be proved.

It has often struck me that the concept of absolute chance has been postulated, in the main, at only the *extreme of the evolutionary scale:* at the primeval level of sub-atomic particles and at the most sophisticated level, the mind of man. Do advances in biology support the conjecture of the spontaneous nature of the human mind—or is it subject to an inexorable fatalism? Judging from the title of a recent book *Chance and Necessity* by the French Nobel prize-winner and molecular biologist Jacques Monod,* one might suspect the former. Jacques Monod offers us 'chance' as the reason for evolution, but as we shall show it is a rigid determinism in disguise. To my mind the main objection to his book is that it suffers from the blight of Parmenides. Parmenides of Elea was a Greek philosopher who held that appearances and change are illusory. He pushed the scepticism of Heraclitus regarding the senses to the limit and appealing to the reason maintained that the world is solid body, pure matter, a corporeal plenum. The Parmenidean doctrine and its consequences was acutely analysed by Aristotle, 'their (the followers of Parmenides) view will be, not that all things are one, but that they are nothing'. The richness and spontaneity of life has disappeared and all that is left is a body, spherical, perfectly homogeneous and motionless. Monod, a faithful disciple of Parmenides, tells us that once we understand the structure of the genetic material (Deoxyribonucleic acid, D.N.A. for short) common to all living beings and the manner in which it undergoes change, the biosphere and the stupendous evolutionary history of man becomes clear. But does it? Meyerson in his remarkable book *Identity and Reality* points out the dangers of this type of scientific reasoning, i.e. explaining reality (things as they are) by pointing to an underlying substratum (the error of Parmenides). To explain in the scientific sense consists in showing that beneath 'appearances', which involve novelty, there is something which remains identical. The unchanging substratum in the biosphere for Monod is D.N.A. and the changes of sequence it undergoes. Monod makes the doctrine of Parmenides easier to swallow by offering us in place of one large piece

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of matter an alphabet of 24 pieces, the four nucleotides of D.N.A. and the twenty amino acids present in the biosphere. Before considering the validity of explaining man in this way, it is worth-while considering briefly Monod's account.

It was the biologists of Monod's generation who had the excitement of discovering the virtual identity of cellular chemistry throughout the entire biosphere. However, the gradual unfolding of this truth made the problem of reproductive invariance still more acute and paradoxical. As Monod remarks, 'If, chemically, the components are the same and are synthesised by the same processes in all living things, what is the source of their prodigious morphological and physiological diversity? And, still more puzzling, how does each species, using the same materials and the same chemical transformations as all others, maintain, unchanged from generation to generation, the structural norm that characterises it and differentiates it from every other'? The problem is to explain the remarkable stability of species (e.g. the oyster 150 million years ago had the same appearance, and probably the same taste, as the oyster of today) and yet allow for evolution. Proteins are the essential molecular agents of teleonomic performance in living things. By teleonomic performance Monod means the oriented, coherent and constructive activities of the cell. In many ways living things are comparable to machines but essentially different in that they have the ability to reproduce and transmit 'ne varietur' the information corresponding to their structure. The process of spontaneous and autonomous morphogenesis is based on the stereospecific recognition properties of proteins and it is primarily a microscopic process before manifesting itself in macroscopic structures.

Having established that proteins are the key to the cybernetics of the cell he notes that the structures of proteins reveal their random nature.

> 'Today we know hundreds of sequences corresponding to various proteins extracted from all sorts of organisms. From the work on these sequences, and after systematic comparison aided by modern methods of analysis and computing, we can now deduce the general law: *it is that of chance.* To be more specific: these structures are "random" in the sense that, even knowing the exact order of 199 residues in a protein containing 200, it would be impossible to formulate any rule, theoretical or empirical, enabling us to predict the nature of the one residue not yet identified by analysis' (*Chance and Necessity,* p. 94).

Here we have Monod's first use of the word 'chance', which is equivalent to saying that we cannot predict the 200th residue any more than we can predict the outcome of the 200th throw of a coin or more appropriately the 200th spin of a roulette wheel with 20 numbers. For there are only 20 amino acid residues present in the

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biosphere. 'The "random" sequence in a protein is reproduced thousands and thousands of times over, in each organism, each cell, with each generation, by a highly accurate mechanism which guarantees the invariance of the structure'.

It should be noted, however, that it is very doubtful whether his scientific facts are correct. In a recent book, *Biochemical Predestination* (McGraw-Hill), D. H. Kenyon and G. Steinman of the Department of Cell and Molecular Biology, San Francisco State College and the Department of Biochemistry, Pennsylvania State University, respectively, present abundant evidence showing that amino acids in proteins are not linked up at random, but rather are apparently highly constrained to link up in certain preferred ways. Furthermore they remark:

> 'If the association of amino acids were a completely random event, it can readily be seen that there would not be enough mass in the entire Earth, assuming it was composed exclusively of amino acids, to make *even one molecule* of every possible sequence of the several distinguishable units in a low-molecular-weight protein'.

In other words 'chance' in the first sense Monod uses it, i.e. randomness, is too rich and nature does not avail itself of it. So if we adopt Monod's sole source of truth, the objectivity of science, we are forced to conclude that the general law of evolution is not one of 'chance'.

At a more fundamental level than proteins we have the inherited material of the cell, D.N.A., Deoxyribonucleic acid. The molecular structure of the 'gene' is a discovery of recent times. Its structure allows it to reproduce a perfect copy of itself and this copy dictates the amino sequence in the various cell proteins. D.N.A. is found in all living things from a bacterium to man with a different arrangement of its various nucleotides, of course. D.N.A. contains four nucleotides each consisting of the sugar deoxyribose and one of four bases. The nucleotides are arranged in a sequence by phosphoric acid links. A particular sequence will faithfully transmit its information in a manner which does not concern us here. Monod points to the 'necessity' inherent in the process. No loophole appears for change.

Accepting his molecular picture he asks how evolution is possible under these conditions. The only source of evolution, from his viewpoint, is some alteration in the nucleotide sequence of the inherited material, D.N.A. If the sequence could be altered, change and evolution become possible, for once the alteration is made it is faithfully preserved and reproduced. Once again he sees that 'chance' is the only possible cause of a mutation in the D.N.A. 'Pure chance, absolutely free but blind, (is) at the very root of the stupendous edifice of evolution'. What does he mean by 'chance' in this context? He looks at three definitions of chance.

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(1) 'Dice and Roulette are games of chance. . . . Chance enters into these purely mechanical and macroscopic games only because of the practical impossibility of governing the throw of the dice, etc'. He does not regard this definition as germane to the present discussion.

(2) 'In other situations it takes on an essential and no longer merely operational meaning. . . . Suppose that Dr Brown sets out on an emergency call to a new patient. In the meantime Jones the carpenter has started work on repairs to the roof of a nearby building. Jones inadvertently drops his hammer whose (deterministic) trajectory happens to intercept that of the physician, who dies of a fractured skull. We say he was a victim of chance. What other term fits such an event, by its very nature unforeseeable? Chance is obviously the essential factor here, inherent in the complete independence of causal chains of events whose convergence produces the accident.

'Now, between the occurrences that can provoke or permit an error in the replication of the genetic message and its functional consequences there is also complete independence'.

(3) 'Finally, on the microscopic level there exists a source of even more radical uncertainty, embedded in the quantum event, to which the 'principle of uncertainty' applies. An event which is hence and by its very nature essentially unpredictable'.

Very few scientists would be prepared to accept that a mutation is a quantum event, as the 'principle of uncertainty' applies only to subatomic processes. Monod fails, then, to substantiate his claim that mutations in D.N.A. of the gene are due to 'chance', i.e. subject to the 'principle of uncertainty'. He seems aware of this and stresses rather his second definition of 'chance' that 'between the determination, however complete, of a mutation in D.N.A. and the determination of its functional effects' . . . one could still see nothing but an 'absolute coincidence' like that defined above by the case of the workman and the physician. The event would still belong to the realm of 'essential chance'.

One wonders, however, whether this tenet of molecular biology is as sacrosanct as Monod would have us believe. Monod stresses, in other words, that the translation of the nucleotide sequence in D.N.A. into the polypeptide sequence of a protein is strictly irreversible, i.e. information is never conveyed in the opposite direction, from protein to D.N.A. This is 'one of the fundamental tenets of modern biology'. Recently, however [Nature *226,* 1198 (1970)], this dogma has been seriously questioned, as Monod admits in a footnote to the English edition of his essay. He replies in defence of his statement, that the principle of irreversibility still applies to the translation of *sequential information.* Even so it is a shaky piece of reasoning and there are no grounds for maintaining that it will not be invalidated in the near future.

So the scientific basis of Monod's book crumbles to one precarious

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tenet, that between the occurrences that can provoke or permit an error in the replication of the genetic message and its functional consequences there is an independence, i.e. *sequential* information is not translated from protein to D.N.A. Not a very sound foundation for a philosophy of man.

Apart from the scientific objections to Monod's essay (and they are considerable) there is a much more fundamental objection which has been developed with exquisite skill by Emile Meyerson. To what extent can scientific explanation erect a true philosophy of man? He would maintain that the 'chance' associated with alterations in the D.N.A. sequence has no more to say about man than the 'chance' of the kinetic theory or the 'chance' of sub-atomic processes.

There are elements in man such as sensation and volition which can never be reduced to purely rational elements, i.e. explained by the laws of nature. Alterations in the nucleotide sequence of D.N.A. is of no help in understanding sensation and volition. As Meyerson remarks, 'The act of volition is free in essence; but as science can embrace only the phenomena subject to the domination of law, we are necessarily led to eliminate this liberty, to treat it as an epiphenomenon'.

This is not to disparage the scientific method but to point to its limitations. By the very nature of its method, i.e. explaining reality by pointing to an unchanging substratum (be it the atoms in the kinetic theory of gases or the D.N.A. of the gene) it can never bridge the gap between a scientific mechanism and the so-called 'irrationals' (Meyerson's terminology) sensation and volition. Cyril Bailey, whose life work was concerned with the Greek atomists and the limits of their scientific explanation of nature, put it in a slightly different way when discussing the philosophical system of Epicurus. 'By attempting to explain psychology on a material basis he exposed himself to the difficulties which must beset any materialist theory which attempts to grapple with the things of the mind and the spirit: it can point to a material counterpart to thought and sensation, but when it attempts to cross the gulf and to say that physical movement is thought and consciousness, it is doomed to failure'.

Profound thinkers like Epicurus, Charles Peirce and Emile Meyerson were struck by the autonomy of human free will. Epicurus sought a reason for it in the depths of matter and postulated the autonomous 'swerve' of the atoms, completely unpredictable and self-determined In doing so he substituted 'chance' for the Gods and Goddesses of Olympus who had previously safeguarded the universe from an inexorable fatalism. Peirce and Meyerson, living in an era when scientific explanation seemed so sure of itself, pointed to its inherent limitations. Sensation and volition, they confidently asserted, can never be explained by pointing to a scientific mechanism. There is no bridge between mechanism and the 'irrationals'. They instinctively recognised that sensation and volition demanded the existence of an inscrutable God, a God who manifests himself with, in and through matter.

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