Deep and Powerful Ordering Forces in the Universe

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The Judeo-Christian concept of God provided the scientist with an ordered universe whose authenticity and rationality was assured by the reliability and rationality of its Creator. This contingent nature of the universe was less appreciated at the time of Isaac Newton because of an image of the world as a machine, a clockwork. However, relativity and quantum theory brought about a drastic revision of views of space, time and causality, and revived the concept of contingent order. Recent developments in the study of far-from-equilibrium processes demonstrate that deep and subtle ordering forces are at work even in what were thought to be random processes. There is a wholeness to the universe that cannot be broken.

I. Introduction

Ancient ideas of divine order in the universe were strongly biased toward polytheistic notions of a nature influenced in an arbitrary way by competing deities. By contrast, the Old Testament description of Genesis presents a picture of a single all-powerful deity whose creative activity is orderly, purposeful and good. The New Testament lends even greater distinction to the work of this transcendent God by revealing His intense ongoing concern for the order of this material world He had made. The Apostle Paul, in his letter to the Colossians, and the writer of the letter to the Hebrews both emphasize the immanent activity of God in His universe ("By Him all things consist," Colossians 1:15; "He upholds all things by the word of His power," Hebrews 1:3).[1]

The deep significance of this ordering principle has been increasingly appreciated, with the development of relativity theory, through the major philosophical upheaval of quantum theory and the uncertainty principle, and in the current studies of the relationship of order to disorder by Mitchell Feigenbaum, Ilya Prigogine and David Bohm. It is becoming increasingly evident that there are deep and powerful forces stipulating order in the universe.

II. Historical Scientific & Theological Views of Order

A. Contrast Between Greek & Judeo-Christian Views of Mankind

Theologian Thomas Torrance has stated that three major traditions have contributed to the understanding of mankind which prevails in modern Western culture.[2] The Greek and Roman traditions alike were characterized by a radical dualism of body and mind or soul, whereas the Hebrew tradition was distinctly nondualist, with body and soul forming an integrated unity. These distinctions have given rise to deep tensions which he says we must endeavor to understand as we function in a scientific-technological culture.

Greek dualism elevated the mind to almost God-like status, to a transcendent position where man could be occupied with enteral ideas such as truth, harmony, goodness and beauty. Earth and its mundane sensibilities were of less consequence. The result was what Torrance calls "a persistent rationalistic disjunction of theory from practice." The Romans had a different type of dualism, one that separated body from soul by virtue of an emphasis on the material realm. The Roman mind, he points out, was intensely pragmatic, focused on the business of technical achievement and devoted to law and order—to the respected and feared Roman justice. Rome built; their goals were an invincible army, a stable society, an incredible power structure.

In the Incarnation, God takes on the form of man, assumes a place of suffering and struggle alongside His creatures, and in so doing confers on His earthly creation a greater sense of both reality and importance.

By contrast, the Hebrew view was a unitary one. The one God, who ruled the universe, was intimately concerned with the fortunes of His creatures. He was involved in every aspect of their society, and they were actually His earthly agents for the blessing of mankind.

As Torrance says:

> It was characteristic of the Hebrew unitary view of body and soul . . . that the spiritual and the physical were not disjoined but held to be interlocked under the sustaining and holy presence of God. This is very evident, for example, in the teaching of the Old Testament about religious cleanness and uncleanness in physical life and behaviour, which is so foreign to any outlook governed by a sharp dualism of mind and body. But it is particularly evident in the conviction that God and his people were so closely bound together in the fulfilment of his supreme purpose for mankind in history, that he was not regarded as shut out of human affairs, infinitely exalted and transcendent though he is. God and his people were thought of as forming one covenanted society within the conditions of their earthly existence, while they on their part did not need to reach beyond those conditions or escape into some realm of timeless abstractions to enjoy spiritual communion with him. Integral to this Hebrew outlook was an essentially religious view of man, for human beings were regarded as related to one another and to the physical creation through the intimate presence of God and in reliance upon the constancy of his faithfulness and steadfast love. Hence, instead of religion being hived off into some arcane realm of its own, it became the inherent force affecting the way human beings regard and behave toward one another, and making for creative integration in everyday human life, thought and activity.[3]

Implied in the Hebrew conception of man's relationship to God was also a sense of personal relationship. God desired our love, and He also desired us to love our neighbors.

When we come to the Christian era, this sense of the personal is confirmed and greatly extended. In the Incarnation, God takes on the form of man, assumes a place of suffering and struggle alongside His creatures, and in so doing confers on His earthly creation a greater sense of both reality and importance.

B. The Concept of Order

The crucial importance of the Judeo-Christian conception for our consideration of order lies in this emphasis on the transcendent God's intense interest in His creation and in His creatures. Not only was God, in the Christian view, an active participant in His world, but He had created it out of nothing, along with space and time. He was not, then, simply the First Cause and therefore part of what was made. Instead, everything that existed owed both its origin and its continuation to His creative will. Stanley Jaki, in *Cosmos and Creator*, discusses the distinctly Christian roots of the doctrine of creation out of nothing, or *creatio ex nihilo*, and attributes its first use to the theologian Tertullian (c. 200 A.D.). Its acceptance as a Christian doctrine was immediate and widespread, not only because it was consistent with the first chapter of Genesis, where the heavens and earth have their "beginning" through the all-powerful God, but also because it was a necessary emphasis in confrontation with the Hellenistic philosophy in which the world was considered eternal and divine. Jaki says of the doctrine:

> What is most telling about that declaration is its entry into Christian literature from the very beginning and the matter-of-fact manner in which that entry had been accomplished. There is no hesitation whatever on the part of those writers concerning the appropriateness of 'from what was not existing' to convey the true meaning of the making of the world by Almighty God. This is certainly a striking contrast with the Greeks' attitude toward the notion of creation out of nothing. That attitude was a spontaneous dismissal, nay scorn, of the whole idea. This is why it occurs only half a dozen times in the vast corpus of classical Greek literature. . . . The Greeks of old simply could not think of a God who had a truly creative power over the universe. More often than not God, or rather the divine, was merely the noblest part of the universe. Aristotle, for one, most emphatically warned that the universe should be thought of as an orderly house but without a master, or a well-ordered army but without a commander.[4]

To get at the significance of the Judeo-Christian development in our understanding of the nature of order in the universe, we need to consider the concept of contingence.

C. Contingence & Contingent Order

When events are referred to as contingent, we mean that they just happen to be a certain way. However, in a fuller sense, we also imply by the word contingent that things do not have to be that way, and it is in this sense that the term has been applied to the Judeo-Christian concept of a universe created *ex nihilo*. Thomas Torrance deals with this application of contingence in the preface to his book *Divine and Contingent Order* as follows:

> In the history of thought this fuller sense was bound up with the Judeo-Christian conception that God freely created the universe out of nothing. This does not mean that he created it out of some stuff called 'nothing', but that what he created was not created out of anything. To think of the universe as having been brought into being in this way is to hold that the universe has been given a distinctive existence of its own, utterly different from God's. We describe it as contingent for it depends on God entirely for its origin and for what it continues to be in its existence and its order. The baffling thing about the creation is that since it came into being through the free grace of God it might not have come into being at all, and now that it has come into being it contains no reason in itself why it should be what it is and why it should continue to exist. Indeed God himself was under no necessity to create the universe.[5]

The impact of this view of the Creation was profound. If indeed the universe had a distinctive existence of its own, then it must also be endowed with its own authentic reality and integrity. Furthermore, its orderliness must also be contingent, being neither self-sufficient nor self-explanatory but rather having a reliability and rationality which depend upon and reflect God's own reliability and rationality. Since the universe is the free creation of an infinite God, we should not expect to be able to anticipate its character, but instead to be constantly surprised by its limitless variety of pattern and structure. As Torrance expresses it:

> It is because . . . freedom and rationality within the universe are contingent upon the infinite freedom and inexhaustible rationality of God that the universe meets our inquiries with an indefinite capacity for disclosing itself to us in ways which we could not suspect, manifesting structures or patterns which we are quite unable to anticipate *a priori*[6].

Yet our attitude toward this fascinating universe is not to be one of worship, for it is, like ourselves, a created thing. Thus, our investigation into its order is wholly appropriate, as God's servants seeking to "subdue the earth" and having "dominion" over the rest of its creatures.[7] In Donald MacKay's words, we are not an "unwelcome interloper," but rather "the servant-son at home in his Father's creation."[8] The distinctiveness of the Christian position is further brought out by R. Hooykaas in his *Religion and the Rise of Modern Science*:

> The Bible knows nothing of 'Nature' but knows only 'creatures', who are absolutely dependent for their origin and existence on the will of God. Consequently, the natural world is admired as God's work and as evidence of its creator, but it is never adored. Nature can arouse in man a feeling of awe, but this is conquered by the knowledge that man is God's fellow-worker who shares with Him the rule of the fellow-creatures, the 'dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth. . . . ' Thus, in total contradiction to pagan religion, nature is not a deity to be feared and worshipped, but a work to be admired, studied and managed. In the Bible God and nature are no longer both opposed to man, but God and man together confront nature.[9]

D. Order & Contingence in the Medieval Period

Admiring God's work, then, was the fundamental basis for the scientific study of the universe. Its acceptance led, according to Torrance, to a brief period of scientific fruitfulness in the physics of space, time, light and motion in Alexandria in the fifth and sixth centuries, but was followed by a long period of quiescence due to a resurgence of the Greek ideas of causality.[10] Still retained was the idea of the created universe as rational because its Creator and Preserver was rational—so crucial to our scientific understanding of the universe—but largely lost was the idea of contingence.

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Instead, theologians preferred an emphasis upon the impassibility and immutability of God (i.e., God is not subject to suffering or change) which became allied with the Aristotelian idea of God as the Unmoved Mover.

Historian Lynn White, Jr. provides some valuable insights into the forces operating in the Medieval period which led to this narrowing of the concept of order in the universe.[11] By the year 1100 A.D., a Christian Latin theology was emerging which placed strong emphasis upon the transcendence of the Creator. God was above all human comprehension, and His action was seen to occur, ordinarily, by means of "secondary causes" which included the agency of His creature man. Since God had given man both freedom of will and powers of intellect, human judgement could be a reliable resource for establishing civil law and for understanding the order of the universe. Human will and intellect were assumed, of course, to be operating within the framework of the Creator's design, but the latter's will was increasingly seen to be expressed in the form of immutable laws; the so-called "laws of nature" (*lex naturae*). God orders His Creation by means of these established laws which man is to comprehend and obey. Otherwise, God's influence is distant and subtle. White sums up the emphasis of the Medieval Latin theology:

> Law, then, is inherent in God's purpose for all his creatures. It follows that he cannot be expected to tamper with it frequently in special circumstances. God is chiefly praised by the perfection with which his creatures exist according to the laws which he has established for and in them.[12]

This twelfth-century drive to stress the omnipotence of God and His underlying order was accompanied by a wave of translating scientific works from both Greek and Arabic sources. Among these authors was Aristotle, a scholar of tremendous intellect and remarkable breadth of knowledge. Unfortunately, he was also a pagan, which led to a resurgence of ideas of an eternal world, of gods and all else bound by inherent necessity, and of a universe without freedom. To combat these pagan aspects of the Aristotelian system, Thomas Aquinas proceeded to reinterpret Aristotle in a way which preserved essential Christian doctrines such as creation and personal immortality, demonstrating their logical consistency with a context ruled by human reason. This approach posed a tremendous threat to the Church's concept of the absolute omnipotence of the Creator and His revelation in Scripture. As White puts it:

> If sweet reason could provide so broad a foundation for Christian faith, the need for revelation was being called into question. To them the Thomistic-Aristotelian synthesis was a Trojan horse of resurgent paganism.[13]

The Church, in the form of Etienne Tempier, bishop of Paris, struck back within a few years of Aquinas' death with a pronouncement of automatic excommunication for the teaching of many Aristotelian and even Thomistic propositions. It further demanded that natural philosophers start thinking about nature in non-Greek terms. The result was a revitalization of philosophical thought during the next two centuries, in which the concept of causality was greatly narrowed and a strong inclination developed toward a purely empirical examination of natural phenomena.

According to Torrance, by the sixteenth and seventeenth centuries, scientists had rejected the view that in understanding the world the human mind required an antecedent set of ideas and concepts which owed nothing to experience.[14] Instead, they understood that the ideas and concepts were derivable from the world itself by empirical examination. The most unique feature of this approach was that experiments were designed to encourage the discovery of coherent patterns which could not otherwise be known, and then these patterns were used to generate explanatory theories. Once again, the stimulus for this new thrust in the scientific study of the world came as a result of a resurgence of the Christian doctrine of creation out of nothing, at the time of the Reformation. The result of this revival was to introduce once more the concept of a universe continuously depending upon God for its reality and its order; a contingent universe.

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E. Newtonian Order

The new community of scientists, largely devout believers but convinced of the importance of the predominant role to be played by human reason, found a philosophical leader in Isaac Newton. He was a deeply religious man, and his conception of the relationship of God to the universe was pivotal in his thinking. According to Newton, the universe owed its rationality to the ultimate rationality and stability of God its Creator. Yet there was, in Newton's view of God's relationship with the universe, a strange inconsistency; for he saw God as unmovable and detached in His absoluteness, yet at the same time the immanent source of its precision and consistency. The latter was especially important where there were what Newton observed as "irregularities" in the systematic motions of the planets and stars. As Torrance points out in *Divine and Contingent Order*, this latter "regulative" function had unfortunate consequences for the future relationship between science and theology, for, as scientific explanations improved the irregularities disappeared, and with them the need for the immanent Creator.[15]

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Newton also addressed the question of the mechanistic explanation in its relationship to the origin of the universe, emphasizing the very important point that the origin of the universe's immanent order is not completely explainable by reference to the mechanical system itself but depends rather upon a different cause: the will and counsel of its Creator. Newton's "strangely ambiguous conception" of God's ordering activity is summed up by Torrance as follows:

> On the one hand Newton's God is inertially attached to the universe in a grand synthesis which makes him through absolute time and space the supreme regulative principle by which the whole system of the world is held together, while on the other hand he is so transcendently related to the universe that he is deistically detached from it in his eternal impassibility and immutability. Through identifying absolute time with the eternal duration of God, and absolute space with the infinite presence of God, which together constitute the medium in which all things are contained, structured, and moved, Newton accounted for the natural and immutable order of the universe which operated through mechanical causes and with mathematical precision. Nevertheless, mechanical causes of that kind, Newton claimed, could not be extrapolated to account for the origin of the kind of order that obtains within the universe—for that a different kind of 'cause' is required, 'the agency of will'. Expressed differently this means that the laws of nature do not apply to those creative processes by which what is nature came into being, but only to those observable processes of a nature that is already in being. This is a point of considerable significance, for it means, in Newton's view, that the universe cannot be conceived to be a mechanical system complete and consistent in itself, for its immanent order is not completely explainable within that system, but the universe may be conceived as a consistent mechanism if it is related to 'the counsel' of a 'voluntary and intelligent Agent' beyond it, the living God who rules over all.[16]

Torrance goes on to discuss the aforementioned regulative role of the Creator and then emphasizes one primary point of Newton's system which is critical for our appreciation of current views of universal order. This was his recognition that the universe is not reducible to a mechanical system, that it is not complete and consistent in itself, but requires a non-mechanical Agency to complete its intelligibility and make it accessible to scientific investigation.

III. Modern Science & the Revival of Contingent Order

Admittedly, it was difficult in Newton's day to appreciate the need for the immanent Creator, constantly willing the order and consistency of His Creation, especially as philosophers of that time attempted to define the whole realm of nature with all its multivariable phenomena in terms of exclusive mechanical law. But with the advent of Einstein and his theory of special relativity, a massive shift began in the way scientists viewed the physical world.[17] Einstein demonstrated that matter and energy are related by the equation $E = mc^2$, where c is the constant and universal value for the velocity of light. Of special importance, the speed of light is the same regardless of the motion of the observer, and mass is found to increase as an object's velocity approaches the speed of light. The fundamental changes for our consideration of order were that space and time were not longer separate entities, but were more correctly a single entity—space-time—and matter was seen as a form of energy. Within another decade, Einstein had propounded his second great theory, General Relativity. This theory dealt with gravitation, which was presented as a mathematical expression that involved the distortion of space-time. The profound implication of curved space-time was that the universe was finite, a conclusion which ultimately led to the "big-bang" theory for the origin of the universe. Most importantly, where Newton had absolutized time and space, relativity theory showed time to be an intrinsic ingredient of the transformations of matter, and space was seen no longer as empty but rather filled with energy and matter. When we come to space-time, we see a picture of what Torrance calls:

> a continuous, dynamic material field, with a reciprocal action between it and the constituent matter and energy of the universe, unifying and ordering everything within it.[18]

The liberating activity of Einstein's work to loose science from the Newtonian yoke is expressed by Torrance as follows:

> Newton insisted on presenting the dynamic universe and interpreting continuous motion within the *idealized* framework of a geometry of relations between rigid bodies independent of time. This had the effect of clamping down upon everything in the universe a hard deterministic or mechanical structure. If that idealized Euclidean framework is dismantled, then the universe is found to manifest itself, not as a closed deterministic system, but as a continuous and open system of contingent realities and events with an inherent unifying order. As such its internal consistency must finally depend on relation to an objective ground of rationality beyond the boundaries of the contingent universe itself. That is, as I understand it, the effect of Einstein's reconstruction of classical physics: a finite but unbounded universe with open, dynamic structures grounded in a depth of objectivity and intelligibility which commands and transcends our comprehension.[19]

If Einstein's work opened the door to new and unexpected relationships between time and space, matter and energy, then the advent of quantum theory shook the very foundations of the edifice of science. In Newtonian mechanics, it was assumed that the description of the initial state of any system allowed an accurate prediction of its state at any future time. In the past 50 years, physics has abandoned strict causality of this kind by virtue of the demonstration by Heisenberg that there is an element of uncertainty when we attempt to simultaneously establish both position and velocity of elementary particles. The precise orbits of planetary electrons in atoms were now seen as idealizations. In the words of Donald MacKay:

> If we try to establish the exact position and speed of two atomic particles which are going to collide, we will never be able to do it accurately enough to determine exactly how they will rebound. The more exactly we observe the position, the less exactly we can specify the speed, and conversely. So the most elementary process envisaged by the mechanistic theory of classical physics—the action of one particle on another—turns out not to be precisely calculable. The cog-wheels of the classical clockwork model of the universe seem to have loose teeth! This has, of course, made a tremendous difference to the theory and practice of atomic physics. Moreover, it does mean that in our present thought-model of the physical universe as a whole, absolute causality, in the sense of the unwinding of everything predictably from the initial conditions, has gone.[20]

The significance of quantum indeterminacy for our consideration of order is that a way is now open for chance, in its contingent sense, to interact with the "laws of nature." As Polkinghorne points out, the interplay of chance and lawful necessity is the way the world develops new directions and possibilities.[21] The contingent nature of these apparently random processes is evidenced by their intelligibility and their fruitfulness. As he says:

> The universe is full of the clatter of monkeys playing with typewriters, but once they have hit on the first line of ***Hamlet*** it seems that they are marvelously constrained to continue to the end of at least some sort of play.[22]

However, this apparent role of randomness in the fundamental workings of the universe has been, for many in science, a sign of emptiness and meaninglessness. Jacques Monod speaks of man's aloneness "in the unfeeling vastness of the universe," and Stephen Weinberg's conclusion is that it is all pointless.[23] But, in fact, if we understand change as contingent upon a higher intelligibility and rationality, we can search for and find deeper meaning and a powerful ordering structure behind the whole panorama of events in the universe.

To combat pagan aspects of the Aristotelian system, Thomas Aquinas proceeded to reinterpret Aristotle in a way which preserved essential Christian doctrines . . .

Torrance's recommendation to the scientific community is to be done with the "chance-necessity dialectic," and instead to see what appears accidental as coordinated with a higher kind of order, as did Heisenberg when he claimed that the accidental was rather more subtle than we imagined and related to "the central order of things."[24] Torrance goes on the suggest that we also take a "trajectory of temporal motion into our basic equations" in order to comprehend the subtle cohesion of contingent events.[25] The latter would be especially valuable in our understanding of the remarkable unidirectional processes of the universe, including evolutionary directions in living systems and in the expanding cosmos.

Indeed, it is recent developments in research on these non-linear processes which lead to a new appreciation of the depth and power of ordering forces in the universe.

IV. Recent Developments Pointing to Deep & Powerful Ordering Forces

A. Thermodynamics of Far-From-Equilibrium Systems

1. Order Through Fluctuations

Belgian Nobel laureate Ilya Prigogine tells us that the science of thermodynamics brought with it a new concept of time as unidirectional.[26] The mechanistic world view which dominated Western science from the time of Newton had sought to organize nature into all-inclusive schemes, universal frameworks in which all the parts were logically or causally interconnected. There were to be no gaps left open for spontaneous, unexpected events which were not wholly explicable on the basis of the immutable laws of nature. But by the middle of the nineteenth century, scientists were introducing new concepts which had to do with heat engines and energy conversion, and the science of thermodynamics was born. One of its key components was the Second Law, which introduced the idea of disorder or "entropy," and explained the frequently observed inefficiency associated with energy conversion. In these cases, some of the energy had been converted to an unusable form represented by the increased molecular disorder of the system. The implication of the Second Law of Thermodynamics was far-reaching; there was an irreversible direction to natural processes. Time had an arrow, and it pointed in the direction of an inescapable loss of energy in the universe. The new thermodynamic ideas about a direction in natural processes were foreign to the machine-minded, who saw the world as clockwork, the planets timelessly orbiting the sun, and all systems equilibrating and operating in a deterministic fashion. The response of the mechanists was to regard the irreversible processes with which thermodynamics was concerned as rare and inconsequential.

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Prigogine's thesis is that irreversible processes are in fact the predominant kind, and classical mechanics succeeds only as it idealizes otherwise irreversible processes by ignoring friction and other limiting features. And, of utmost importance, in moving from the reversible equilibrium situation to the irreversible far-from-equilibrium one, a whole new character of natural processes is revealed, and a new kind of order appears. Examples of these ordering processes come readily to mind. The flow of water from a faucet goes through a series of ordered structures as the flow rate is changed. Superconductivity in metals at certain low temperatures reveals a collective ordering of electrons. Living systems reveal a very high level of order in what are, of necessity, far-from-equilibrium conditions. One of the most fascinating visual effects is seen in a chemical phenomenon called the Belousov-Zhabotinsky reaction. When malonic acid, bromate, and cerium ions are placed in sulfuric acid in a shallow dish at certain critical temperatures, a series of pulsating concentric and spiral circles are seen to develop, just as if they were life forms. This behavior is the result of giant oscillations of millions of molecules, operating in concert, in the reaction system. The key feature of this kind of chemical phenomenon is the presence of autocatalysis; one or more of the reacting species is able to catalyze its own synthesis, and the whole system seems to pivot on this autocatalytic step. In contrast to chemical reactions in which reagents and products are distributed randomly in the solution, in the Belousov-Zhabotinsky type of reaction there are local inhomogeneities; in one region, one component may predominate, while in another part of the reaction vessel its concentration may be exhausted. The cooperative effect of a vast number of such reactant molecules leads to the pulsating, highly ordered arrangements. It is Prigogine's thesis that these structures are the inevitable consequences of far-from-equilibrium reactions. The term he uses for this phenomenon is "order through fluctuation."

A simpler type of far-from-equilibrium chemical system is the chemical clock, studies by Prigogine and his collaborators by means of a model which he refers to as a "Brusselator." The model is distinguished by another kind of catalytic feature, "crosscatalysis," in which two components reciprocally affect each other's synthesis. The fluctuations in this model system are found to be of a highly specific periodicity, reflected in a remarkable change in composition, from all of one component to all of a second component, practically instantaneously. Here we have an example of oscillations in time. In the Belousov-Zhabotinsky reaction the oscillations are both time-and space-dependent, with waves of the two predominant species of molecules passing periodically through the system.

Another instance of order through fluctuations, this time in a physical system, is the Bernard instability, in which one heats a liquid layer from the bottom and thereby establishes a temperature gradient from bottom to top. At low temperature differences, heat is transferred simply by conduction and the fluid as a whole remains at rest. But at some critical temperature value a convection current appears spontaneously, and a huge cooperative movement of the molecules of the liquid occurs which forms a grid of hexagonal cells. Prigogine emphasizes that according to the laws of statistics the original microscopic convection current should have been doomed to regression. Instead, the minute fluctuation is amplified until it invades the entire system. As Prigogine expresses it:

> Beyond the critical value of the imposed gradient, a new molecular order has been produced spontaneously. It corresponds to a giant fluctuation stabilized through energy exchanges with the outside world.[27]

2. *The Living System*

If non-linear autocatalytic reactions are somewhat uncommon in the inorganic world, they are the rule when one examines the metabolic processes of the living system. The characteristic of living things is homeostasis, the maintenance of an ordered flow of energy to the cells and tissues of the organism and a conversion of that energy into useful structure and needed function. The metabolic pathways of the thousands of components involved are regulated by feedback loops and crosscatalytic steps rather similar in character to those of chemical clocks. Prigogine has noted one interesting distinction between the inorganic and the biological—the existence of complexity in the reaction mechanism in the former and of complexity in the reacting molecules (the proteins, nucleic acids, *etc.*) in the latter. This he attributes to the uniqueness of the biological system in having "a past": the complex biomolecules are a product of evolutionary selection to perform a highly specific function.[28]

Prigogine goes on to illustrate the extent to which metabolic processes in living systems demonstrate the character of fluctuating, self-ordering systems. For this he uses the well-characterized process of glycolysis, the fundamental energy-producing cycle during which the sugar glucose is broken down through a series of metabolic reactions to yield the energy-rich substance ATP (adenosine triphosphate). Each glucose molecule degraded leads to the conversion of two molecules of ADP (adenosine diphosphate) into ATP, and the ATP is recycled into ADP as its high energy is utilized in metabolism. It has been demonstrated that this metabolic sequence displays oscillatory behavior and that its rate-controlling steps operate at far-from-equilibrium conditions. In Prigogine's words:

> Biochemical experiments have discovered the existence of temporal oscillations in concentrations related to the glycolytic cycle. It has been shown that these oscillations are determined by a key step in the reaction sequence, a step activated by ADP and inhibited by ATP. This is a typical nonlinear phenomenon well suited to regulate metabolic functioning. Indeed, each time the cell draws on its energy reserves, it is exploiting the phosphate bonds, and ATP is converted into ADP. ADP accumulation inside the cell thus signifies intensive energy consumption and the need to replenish stocks. ATP accumulation, on the other hand, means that glucose can be broken down at a slower rate.
>
> Theoretical investigation of this process has shown that this mechanism is indeed liable to produce an oscillation phenomenon, a chemical clock. The theoretically calculated values of the chemical concentrations necessary to produce oscillation and the period of the cycle agree with the experimental data. Glycolytic oscillation produces a modulation of all the cell's energy processes which are dependent on ATP concentration and therefore indirectly on numerous other metabolic chains.
>
> We may go further and show that in the glycolytic pathway the reactions controlled by some of the key enzymes are in far-from-equilibrium conditions. Such calculations have been reported by Benno Hess and have since been extended to other systems. Under usual conditions the glycolytic cycle corresponds to a chemical clock, but changing these conditions can induce spatial pattern formations in complete agreement with the predictions of existing theoretical models.[29]

The mechanistic world view which dominated Western science from the time of Newton had sought to organize nature into all-inclusive schemes, universal frameworks in which all the parts were logically or causally interconnected.

Prigogine has also examined the complex aggregation behavior of the slime mold *Dictostelium discoideum*. Depending upon the nutritional state of the environment, the unicellular amoebae can grow and migrate as free-swimming organisms, or, under starvation conditions, undergo a spectacular transformation in which several thousand cells aggregate to form a foot-like structure which provides support for a mass of spores. Prigogine describes the first stage of the aggregation process as beginning with the onset of "displacement waves" in the population of amoebae, directed toward a center of attraction which appears to be produced spontaneously. This migration of cells appears to be in response to a gradient of the biochemical messenger, cycle AMP, first produced by the cell which forms the "attractor center." Here again we see the characteristics of a chemical clock; but here, in this simple differentiation phenomenon, the self-organization mechanism actually leads to communication between the cells. Indeed, one of the hallmarks of these self-organizing systems seems to be their coherence. The individuals involved behave as a unit, as if their movement were the result of long-range forces. Yet preceding these ordering processes there is an inherent instability, as if each system was composed of subsystems which were constantly fluctuating. It is these fluctuations, when powerful enough and timed properly, which can shatter the pre-existing organization and lead to the new level of organization. Prigogine emphasizes that the point of change, the "bifurcation point," is unpredictable; it is indeterminate in the philosophical sense. But it is also unpredictable in direction—whether the transition will be to chaotic behavior or to a new higher level of order.

It is tempting to apply these characteristics of the self-organizing system to the origin of life. Prigogine has suggested that biogenesis may have occurred by just such a progression of events, with simple self-organizing chemical systems reaching points of bifurcation, then, by virtue of available energy, moving to progressively higher forms of complexity and finally to the first primitive cell. In his words: "One would then obtain a hierarchy of dissipative structures, each one enriched further by the informative content of the previous models through the 'memory' of the initial fluctuations which created them successively."[30] Peacocke's excitement about this possible route to life is apparent as he says:

> Because of the discovery of these dissipative systems, and of the possibility of 'order-through fluctuations,' it is now possible, on the basis of these physico-chemical considerations, to regard as highly probable the emergence of those ordered and articulated molecular structures which are living. Instead of them having only an inconceivably small chance of emerging in the 'primeval soup' on the surface of the earth before life appeared, we now see that ordered dissipative structures of some kind will appear in due course. To this extent, the emergence of life was inevitable, but the form it was to take remained entirely open and unpredictable, at least to us.[31]

We seem now to be back to the picture of a contingent order, built into the stuff of life by the Creator. The living system remains unpredictable by virtue of its sheer complexity but also because an openness, a multiplicity of bifurcation points, appears to be inherent in its origin and in its operation.

3. *Universal Constants in Chaotic Behavior*

The mathematical analysis of non-linear phenomena has proved difficult. The usual approach to these many and varied systems is to simplify them to approximate a linear situation. Arthur Fisher, in an article in *MOSAIC*, quotes a graduate student at Los Alamos National Laboratory's Center for Nonlinear Studies as saying:

> Your textbook is full of linear problems, and you become adept at solving them. When you're confronted with a nonlinear problem, you're taught immediately to linearize it; you make an approximation, use a special case. But when you venture into the real world, you realize that many problems are non-linear in an essential way and cannot be linearized meaningfully. You would just lose the physics.[32]

One of the most fascinating studies of non-linear phenomena is that of Mitchell Feigenbaum, who has found that there are only a limited number of patterns which lead to chaotic behavior. That is, transitions to chaos are *ordered*. One of these patterns is called period doubling, the process by which the periodic behavior of a system alters and finally becomes erratic as a particular parameter (e.g., temperature) is changed. In the usual periodic process there is a fixed time interval between repetitions. As some parameter is changed, this interval does not change gradually or randomly, but is found to double at each change. And the process of successive doubling is found to recur continually until at a certain value of the parameter under change, in Feigenbaum's view, it has doubled ad infinitum, so that the behavior is no longer periodic. Chaos has set in, but by a very precise route of period doubling.

In moving from the reversible equilibrium situation to the irreversible far-from-equilibrium one, a whole new character of natural processes is revealed, and a new kind of order appears.

It is tempting to conclude from the results obtained in this new science of chaotic behavior that there are subtle yet powerful forces of order throughout nature. And the expectation is that there is more to come. As one of the "chaos scientists," David Ruelle, says: "There is a whole world of forms still to be explored and harmonies still to be discovered."[33]

B. Order as Wholeness

In a recent book, *Looking Glass Universe: The Emerging Science of Wholeness*, authors John Briggs and David Peat present the work of a number of scientists who are convinced that the study of the world by disassembling it into parts leads to a very significant distortion.[34] Of special note is the contribution of physicist David Bohm, who insists that some of science's most popular ideas lead to very misleading conclusions. For example, in considering the nature of order, Bohm points out that its opposite is popularly thought to be disorder or randomness. Instead, what appears as disorder may be a condition of a higher degree of order. An example is the profoundly puzzling double-slit experiment.[35] Electrons are considered elementary particles, and photons are considered to be single indivisible quanta of energy. When a stream of photons is fired at a target with two slits in it, the photons will interfere with each other and form an overlapping wave pattern on a screen behind. The same result is obtained if a stream of electrons is fired at the target. However, if photons or electrons are fired at the target one by one, one would expect that, in the absence of interference, a simple scatter pattern would be observed behind each of the slits. Instead, a wave pattern is still obtained, as if all of the electrons had been fired at the same time! Explanations for this phenomenon seemed desperate. One suggestion was that each individual electron somehow goes through both slits and interferes with itself. A second approach proposed that each particle was somehow aware of the fate of its predecessors and those to follow it, and it was the aggregate of these "awarenesses" which led to the wave pattern on the screen. Quantum physicists, rejecting either idea, simply concluded that the laws of physics don't apply to individual particles or quanta—only to large numbers where the rules of probability apply. For David Bohm, the result of the double-slit experiment suggests that a very high degree of order exists where we previously thought we were dealing with the random behavior of individual particles. It is consistent with a picture of a whole or unbroken universe, in which there is no separation into parts which are ordered and parts which are disordered.

A second example of wholeness is seen in the strange behavior of elementary particles studied in high voltage accelerators.[36] When protons are smashed in an accelerator, they divide into a number of other particles, but after several very rapid transitions they are found to return to the form of the original proton. To use Briggs and Peat's term, they "divide back into themselves." A similar behavior is observed when quarks, the presumed fundamental particles, are split away from mesons. The freed quarks immediately recombine to reform new mesons. The quantum mechanical picture is that of a wholeness that can't be divided.

Bohm's "science of undivided wholeness," as Briggs and Peat explain it, is best described by analogy to the photographic phenomenon of the hologram.[37] Whereas an ordinary photograph is really an abstraction, a mapping of certain aspects of three-dimensional reality onto a two-dimensional form, thereby dividing the scene into parts, the hologram is a composite of the entire three-dimensional scene. This is because the holographic image is constructed by directing a laser beam (light of uniform phase) through a holographic plate on which a scene has been recorded in a very special manner. By means of a half-silvered mirror, laser light is split into two beams, one to illuminate the object and the other to act as a kind of reference beam. The light striking the object is scattered and recorded on the plate as a mixture of phases, much like sound from a stereo set. The reference beam, by comparison, contains light all in one phase. The mixing of the two beams at the plate results in an interference pattern. As Briggs and Peat describe it, the result is like "a very fine pattern of light and dark patches, a kind of code."[38]

With this interference pattern recorded on a photographic plate, it is possible to produce a holographic image by shining laser light through the plate and projecting the pattern on a screen. The image produced appears three-dimensional, and the plate itself could be said to contain a record of the reference and scattered beams. The fascinating thing about the holographic record is that *every* part of the plate contains a whole image. If one tears off a piece of an ordinary photographic negative, it contains only a piece of the original picture. But if a piece of a holographic plate is torn off, projection of a laser beam through the fragment gives the *whole* image, though with "diminished crispness."

By the time of Isaac Newton, the universe was largely seen as clockwork, with God, as clockmaker and occasional adjustor, largely distant from His Creation.

David Bohm sees the hologram as a forceful analogy for the whole and undivided order of the universe, a frozen version of what is occurring on an infinitely vaster scale in each region of space all over the universe. The universe is seen as a vast array of light waves and other electromagnetic radiations, constantly interacting with each other and with matter, generating interference patterns which are ever-changing and evolving, recording incalculable amounts of information about the objects and events encountered. Within the record one would expect to find information about an object's geometry, internal structure, and perhaps even the nature of its change with time. Most fascinating, perhaps, is Bohm's idea that these interactions occur even at the subatomic level, where elementary particles, also describable as wave patterns, are capable of interaction with the external wave forms.

As Briggs and Peat describe it:

> Remember that matter is also waves. Therefore the very matter of objects is itself composed of interference patterns which interfere with the patterns of energy. What emerges is a picture of an encoding pattern of matter and energy spreading ceaselessly throughout the universe—each region of space, no matter how small (all the way down to the single photon, which is also a wave or "wave packet"), containing—as does each region of the

holographic plate—the pattern of the whole, including all the past and with implications for all the future. Each region will carry this encoding of the whole somewhat differently, as in fact different "parts" of a holographic plate will each give the whole picture but with slightly different limitations on the number of perspectives from which it can be seen.

It is a breathtaking view, an infinite holographic universe where each region is a distinct perspective, yet each contains all.

Everything mirrors everything else; the universe is a looking-glass.[39]

In David Bohm's words, in his book *Wholeness and the Implicate Order*:

There is the germ of a new notion of order here. This order is not to be understood solely in terms of a regular arrangement of objects (e.g., in rows) or as a regular arrangement of events (e.g., in a series). Rather, a total order is contained, in some implicit sense, in each region of space and time.

Now, the word 'implicit' is based on the verb 'to implicate.' This means 'to fold inward' (as multiplication means 'folding many times'). So we may be led to explore the notion that in some sense each region contains a total structure 'enfolded' within it.[40]

V. Theological Correlates to New Concepts of Order

The pioneers of science marched to the frontier with the conviction that God had created a rational and ordered universe, one which would answer their inquiries rationally, if sometimes surprisingly. Then, too, it was to be enjoyed, to be of benefit, but not to be worshipped, for it was only a creature. But as a creature the universe had an order and an authentic reality which was contingent, being neither self-sufficient nor self-explanatory, but depending upon and reflecting God's own reliability and rationality.

By the late Medieval period, the concept of order was narrowed to place major emphasis on God's transcendence. God's order was seen as expressed in the form of natural laws, and it was human reason which was given the responsibility to discern these fixed rules of the universe. By the sixteenth century, the valid means of discernment had been firmly established as empirical examination followed by the testing of explanatory theories. By the time of Isaac Newton, the universe was largely seen as clockwork, with God, as clockmaker and occasional adjustor, largely distant from His Creation. What was largely lost in this somewhat static view of order was the concept of the universe as contingent.

Revival of the concept of contingent order came with the advent of modern relativity and quantum theory. Space and time were understood to be no longer absolute and in fact were seen to be inseparable. Furthermore, space-time was curved, and the universe was therefore finite. Quantum theory and Heisenberg's Uncertainty Principle eliminated strict causality, opening the way for contingent order—for chance to interact with the fixed laws of nature. From a theological viewpoint, the chance events take on a deep theological meaning, for they may properly be seen as the expressed will of the Creator of a higher kind of order.

The extent of the Creator's power and the strong sense of His presence at every level of the created order is awesome. Yet, by this order He brings coherence and rationality to make what is otherwise totally baffling intelligible, as though the scientific history of our world was like a great musical masterpiece composed for our ears.

Hints of the nature of this order come from the work of Ilya Prigogine on far-from-equilibrium systems. Prigogine stresses the preponderance of these non-linear processes in the universe, their characteristic instability and unpredictability, but also the surprising degree to which perturbations lead to higher and more complex levels of order. In the course of these transitions, large groups of molecules function as units, suggesting a high degree of intermolecular communication. The same type of behavior seems to be a general characteristic of living systems and provides a useful framework to explain their origin. Feigenbaum's work on period doubling of non-linear systems also emphasizes the extent of ordering processes in the universe, for even in transitions from order to apparently random behavior, systems follow quite specific, prescribed routes. So, whether perturbation of a far-from-equilibrium system leads to a higher level of order or to chaotic behavior, the transitions are themselves ordered. Indeed, there appear to be deep and profound ordering forces at work in all natural processes.

Similarly, the implications of Bohm's view of wholeness for a deeper understanding of order in the universe are profound. It would seem very appropriate to explore theological correlates in dealing with this picture of order, this seamless enfolding, in which not only matter and energy but also space and time are brought together in one vast hologram of the universe.

Such a construct demands something or someone even greater as its mediator, and it is intriguing to recall the biblical description of the immanent Creator Jesus Christ, God's Son, given in the letter to the Hebrews:

> He reflects the glory of God and bears the very stamp of his nature, upholding the universe by his word of power.[41]

Donald MacKay tells us, in his *Science and Christian Faith Today*, that we may think of the last phrase, "upholding the universe by his word of power," as "*holding in being* the universe by his word of power."[42] This distinction allows us to rid ourselves of the image of God as only a machine-tender or caretaker, and gives us instead the picture of an immanent Creator, whose intimate involvement with His vast creation at every moment insures its very existence as well as its order. The extent of the Creator's power and the strong sense of His presence at every level of the created order is awesome. Yet, by this order He brings coherence and rationality to make what is otherwise totally baffling intelligible, as though the scientific history of our world was like a great musical masterpiece composed for our ears. Indeed, A.R. Peacocke makes just such an analogy when he writes of God's "music of creation":

> . . . he is more like a composer who, beginning with an arrangement of notes in an apparently simple tune, elaborates and expands it into a fugue by a variety of devices of fragmentation and reassociation; of turning it upside down and back to front; by overlapping these and other variations of it in a range of tonalities; by a profusion of patterns of sequences in time, with always the consequent interplay of sound flowing in an orderly way from the chosen initiating ploy (that is more technically, by inversion, stretto, and canon, etc.). Thus does a J.S. Bach create a complex and interlocking harmonious fusion of his seminal material, both through time and at any particular instant, which, beautiful in its elaboration, only reaches its consummation when all the threads have been drawn into the return to the home key of the last few bars—the key of the initial melody whose potential elaboration was conceived from the moment it was first expounded.[43]

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