LIFEWORK OF DAVID BOHM - RIVER OF TRUTH

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In autumn of 1992, one of the world's greatest contemporary physicists passed away. David Bohm, whose work inspired many people all over the world, died in London. Although he had been recovering from a heart attack suffered the previous summer, he was feeling much better at the time, and on October 27 he felt well enough to go to work. Thus, Bohm spent the last day of his life at Birkbeck College, faithfully working with his colleague Basil Hiley, putting the finishing touches on their book that reinterprets the quantum field theory called Undivided Universe (soon to be published by Routledge, Kegan, and Paul).

As he arrived home from work that day, Bohm had another heart attack and died. David Bohm's contributions to science and philosophy are profound, and they have yet to be fully recognized and integrated on the grand scale that they deserve. This review attempts to summarize the fascinating contributions that emerged from Bohm's passionate quest for truth and to outline their growing impact on other fields. In what follows, it is not necessary to have a background in physics, although a basic familiarity with science will be helpful. It goes almost without saying that a brief review such as this cannot begin to do justice to the depth, richness, and rigor of Bohm's thinking. Nevertheless, the essence, beauty, and importance of Bohm's ideas can be conveyed, which is the intent of this review.

BOHM'S QUEST FOR KNOWLEDGE

Bohm's Early Life

David Bohm was born on December 20, 1917, in Wilkes-Barre, Pennsylvania, a small Polish and Irish mining town. His father was a Jewish furniture dealer, and David's earliest intimations about science came from reading science fiction books as a young boy. No other information about science was available to him in Wilkes-Barre, and young David was fascinated by the dazzling concepts of cosmic forces and vast expanses of space that lie beyond our understanding. He later went to college at Pennsylvania State University, where he graduated with a Bachelor of Science degree in 1939, and then began graduate work in physics at the California Institute of Technology. Later he transferred to the University of California at Berkeley, in order to work with J. Robert Oppenheimer. He completed his doctorate in physics there in 1943.

While still a graduate student in Berkeley, Bohm did pioneering work on plasmas at the Lawrence Berkeley Radiation Laboratory. He discovered that, in a high temperature gas (known as a plasma), electrons that have been stripped away from atoms do not behave as separate individual particles but rather as part of a larger, organized whole. Vast numbers of electrons would produce effects that were highly organized, as if some organic process were orchestrating their collective behavior. Bohm later reflected that these collective movements, which today are called Bohm-diffusion, gave him the impression that the sea of electrons was somehow "alive." This was Bohm's first important discovery in physics, and it hints at the deeper themes of wholeness and interconnectedness that characterize his life's work.

Bohm took a position as assistant professor at Princeton University in 1947. While teaching quantum theory over the subsequent few years, he wrote a textbook entitled Quantum Theory (1951), which remains to this day a classic in the field. Upon completing this work, Bohm became acquainted with Albert Einstein, who was also at Princeton at the time. Einstein told Bohm that he had never seen quantum theory presented so clearly as in Bohm's new book, and the two scientists entered into a series of intensive conversations. 1 During the course of this dialogue, Bohm and Einstein discovered much common ground in their mutual appreciation of quantum mechanics, and together they probed deeply into the theoretical interpretation and ontological significance of quantum theory. These discussions led Bohm to seriously question the prevailing interpretation of quantum mechanics set forth by Danish physicist Neils Bohr and others. Inspired with confidence from this association with Einstein, Bohm embarked upon his own inquiry into the foundations of quantum theory, which led to his unique formulations of it and eventually blossomed into his lifelong quest to understand and describe all of reality.

Around this same time, Bohm demonstrated another important aspect of his character. He had worked with J. Robert Oppenheimer at Berkeley in the early 1940s, and when Oppenheimer and others came under the scrutiny of the ominous McCarthy Committee on Un-American Activities, Bohm was called to testify in 1949. Bohm refused, pleading the Fifth Amendment, and Princeton University informed Bohm that he was never to set foot on campus again. Bohm was arrested and charged with contempt of Congress, went to trial, and was acquitted. Bohm's colleagues sought to have his position at Princeton reinstated, and Einstein reportedly wanted Bohm to serve as his assistant, but Bohm's contract with the university was not renewed. He never again taught in the United States.

Bohm moved to Brazil, where he was professor at the University of Sao Paulo until 1955. There he worked on his second book, Causality and Chance in Modern Physics (1957), which is also widely used today in universities. Leaving Brazil in 1955, he spent two years at the Technion in Haifa, Israel, before moving to Bristol, England, where he and a colleague made another original contribution to quantum physics. They showed that an isolated line of magnetic force is able to affect electrons that pass around it without contacting it, a phenomenon known as the Aharonov-Bohm effect. In 1961, Bohm took a professorship at the Birkbeck College in London, where he remained for the rest of his life.

For the next thirty years, David Bohm's work in physics focused primarily on the fundamentals of quantum theory and relativity theory and their implications in several other fields. He also searched beyond physics, maintaining a long dialogue with the Indian spiritual master, J. Krishnamurti. Bohm's scientific collaborators included Basil Hiley and David Peat, and his books include The Special Theory of Relativity (1966), Wholeness and the Implicate Order (1980), and Science, Order and Creativity (1987, with David Peat). Most of the important ideas in these works are presented in concise and simplified form below.

Before venturing into the rich intellectual landscape of David Bohm's ideas, it might be helpful to convey some notion of his character. The following description comes from Rene Weber (1986), who interviewed Bohm on numerous occasions and maintained an association with him for several years.

"Because of Bohm's international fame, I was quite unprepared for the unusually modest and unassuming, gentle person he turned out to be. He is the paradigm of the committed searcher and researcher, intensely absorbed in his philosophy of the implicate order, on which he lectures all over the world. Bohm looks like the proverbial professor, dressed in casual tweeds and almost always wearing a sweater. He is of average height, with brown hair, hazel eyes, a rather pale face, inward and intellectual in expression, a captivating smile and a quiet, low-keyed manner except on discussing physics, when he becomes animated and almost transformed, punctuating his points with vivid gestures. . . (He is) someone who, through science, perceived a universe of truth, beauty, meaning, even the good, and who made his perceptions come so convincingly alive to others. . . David Bohm seemed imbued with a feeling that whatever lies behind nature is holy." (p. 24)

HOLOMOVEMENT AND THE IMPLICATE ORDER

Thoughts About Thinking

Before delving into Bohm's substantive contributions to science, I will touch briefly on his ideas about language and thought. In his penchant for precision, Bohm analyzed ways that our language deceives us about the true nature of reality. We generally consider ordinary language to be a neutral medium for communication that does not restrict our world view in any way. Yet Bohm showed that language imposes strong, subtle pressures to see the world as fragmented and static. He emphasized that thought tends to create fixed structures in the mind, which can make dynamic entities seem to be static. To illustrate with an example, we know upon reflection that all manifest objects are in a state of constant flux and change. So there is really no such thing as a thing; all objects are dynamic processes rather than static forms. To put it crudely, one could say that nouns do not really exist, only verbs exist. A noun is just a "slow" verb; that is, it refers to a process that is progressing so slowly so as to appear static. For example, the paper on which this text is printed appears to have a stable existence, but we know that it is, at all times including this very moment, changing and evolving towards dust. Hence paper would more accurately be called papering–to emphasize that it is always and inevitably a dynamic process undergoing perpetual change. Bohm experimented with restructuring language in this dynamic mode, which he called the rheomode, in an effort to more accurately reflect in language the true dynamic nature of reality.

A primary tenet of Bohm's thinking is that all of reality is dynamic process. Included in this is the very process of thinking about the nature of reality. If we split thought off from reality, as we are conditioned to do, and then speak of our thought about reality, we have created a fragmentary view in which knowledge and reality are separate. Knowledge is then in danger of becoming static and somehow exempt from the conditions of reality. Bohm emphasizes that "a major source of fragmentation is the presupposition that the process of thought is sufficiently separate from and independent of its content, to allow us generally to carry out clear, orderly, rational thinking, which can properly judge this content as correct or incorrect, rational or irrational, fragmentary or whole, etc." (Bohm 1980, 18). In his writing and talks, he was fond of referring to A. Korzybski's admonition that whatever we say a thing is, it is not that. It is both different from that, and more than that (Korzybski 1950).

The artificial separation of process and content in knowledge becomes especially problematic in systems of thought that seek to encompass the totality of existence (as do grand unified theories in physics, for example). As Bohm notes (Bohm 1980), it then becomes quite easy to slip into "the trap of tacitly treating such a view as originating independently of thought, thus implying that its content actually is the whole of reality. From this point on, one will see, in the whole field accessible to one, no room for change in the overall order, as given by one's notions of totality, which indeed must now seem to encompass all that is possible or even thinkable. . . To adopt such an attitude will evidently tend to prevent that free movement of the mind needed for clarity of perception, and so will contribute to a pervasive distortion and confusion, extending into every aspect of experience." (p. 62)

Bohm goes on to suggest that the movement of thought is a kind of artistic process that yields ever-changing form and content. He intimates that "there can no more be an ultimate form of such thought that there could be an ultimate poem (that would make all further poems unnecessary)" (p. 63). Indeed, imagine a Grand Unified Symphony that encompassed all possible symphonies–past, present, and future–thereby rendering all further musical composition redundant and unnecessary. The idea is preposterous, and yet many physicists, not recognizing their theories as art forms, strive for just such an ultimate scientific theory. In truth, science is essentially a creative art form that paints dynamic portraits of the natural world, using the human intellect as its canvas and the tools of reason as it palette. Bohm was rare among physicists in recognizing this, and he exhibited commensurate humility in the interpretation and extrapolation of his theories.

Wholeness And The Holomovement

David Bohm's most significant contribution to science is his interpretation of the nature of physical reality, which is rooted in his theoretical investigations, especially quantum theory and relativity theory. Bohm postulates that the ultimate nature of physical reality is not a collection of separate objects (as it appears to us), but rather it is an undivided whole that is in perpetual dynamic flux. For Bohm, the insights of quantum mechanics and relativity theory point to a universe that is undivided and in which all parts "merge and unite in one totality." This undivided whole is not static but rather in a constant state of flow and change, a kind of invisible ether from which all things arise and into which all things eventually dissolve. Indeed, even mind and matter are united: "In this flow, mind and matter are not separate substances. Rather they are different aspects of one whole and unbroken movement" (in Hayward 1987, 25). Similarly, living and nonliving entities are not separate. As Bohm puts it, "The ability of form to be active is the most characteristic feature of mind, and we have something that is mindlike already with the electron." Thus, matter does not exist independently from so-called empty space; matter and space are each part of the wholeness.

Bohm calls this flow the holomovement. The component terms holo and movement refer to two fundamental features of reality. The movement portion refers to the fact that reality is in a constant state of change and flux as mentioned above. The holo portion signifies that reality is structured in a manner that can be likened to holography. As is well known, holography is a relatively new type of photography, in which the photographic record is not an image of the object (as in normal photography) but rather a set of interference patterns made by splitting a laser beam, and then reflecting one component of the beam off the object before reuniting the two component beams at the photographic plate. When laser light is shined on the hologram, a full three-dimensional image of the object appears, as opposed to the usual two-dimensional photograph. What is especially remarkable about a hologram is that if laser light is shined on just a small part of it, the entire image still appears, although in less refinement and detail. Thus, each small portion of the hologram contains information about the entire image, whereas in a normal photograph, each small portion of film contains a correspondingly small part of the image. As laser light is shined on successively smaller portions of the hologram, the entire image is still preserved, but it becomes progressively more "fuzzy."

In analogy to holography but on a much grander scale, Bohm believes that each part of physical reality contains information about the whole. Thus in some sense, every part of the universe "contains" the entire universe very remarkable claim that at first seems, perhaps, implausible. Yet we have all experienced a glimmer of this in the following commonplace example. Imagine yourself gazing upward at the night sky on a clear night, and consider what is actually taking place. You are able to discern structures and perceive events that span vast stretches of space and time, all of which are, in some sense, contained in the movements of the light in the tiny space encompassed by your eyeball. The photons entering your pupil come from stars that are millions of light-years apart, and some of these photons embarked on their journey billions of years ago to reach their final destination, your retina. In some sense, then, your eyeball contains the entire cosmos, including its enormous expanse of space and immensity in time–although, of course, the details are not highly refined. Optical and radio telescopes have much larger apertures, or "holographic plates," and consequently they are able to glean much greater detail and precision than the unaided eye. But the principle is clear, and it is extraordinary to contemplate.

Evidence for this kind of holographic structure in nature has emerged recently in the burgeoning field of chaos theory and its close cousin, fractal geometry. The term chaos theory is somewhat of a misnomer because the new discoveries are more about order than chaos. It has been found that most nonlinear systems embody a multitude of self-similar structures that are nested within one another at different scales. A well-known example is the Mandelbrot set, which is a fractal that appears in computer representations much like a black bug, with an infinity of similar "bugs" embedded at innumerable smaller scales. Each of these "bugs" replicates the whole, in a sense, and contains information about the entire nonlinear process.

Putting the holographic structure of reality together with its perpetual dynamism, we get the holomovement: an exceedingly rich and intricate flow in which, in some sense, every portion of the flow contains the entire flow. As Bohm puts it, the holomovement refers to "the unbroken wholeness of the totality of existence as an undivided flowing movement without borders" (Bohm 1980, 172). The physical evidence that forms the basis for postulating the holomovement comes primarily from Bohm's interpretation of physics, especially quantum theory, which I will examine further.

The Implicate Order

The holomovement is, admittedly, a rather subtle concept to grasp; indeed, it is generally invisible to us. Bohm proposes that the holomovement consists of two fundamental aspects: the explicate order and the implicate order. He illustrates the concept of the implicate order by analogy to a remarkable physical phenomenon. Consider a cylindrical jar with a smaller concentric cylinder (of the same height) inside it that has a crank attached, so that the inner cylinder can be rotated while the outer cylinder remains stationary. Now fill the annular volume between the two cylinders with a highly viscous fluid, such as glycerine, so that there is negligible diffusion. If a droplet of ink is placed in the fluid, and the inner cylinder is turned slowly, the ink drop will be stretched out into a fine, thread-like form that becomes increasingly thinner and fainter until it finally disappears altogether. At this point it is tempting to conclude that the ink drop has been thoroughly mixed into the glycerine, so that its order has been rendered chaotic and random. However, if the inner cylinder is now rotated slowly in the opposite direction, the thin ink form will reappear, retrace its steps, and eventually reconstruct itself into its original form of the drop again. Such devices have been constructed, and the effect is quite dramatic.

The lesson in this analogy is that a hidden order may be present in what appears to be simply chance or randomness. When the ink form disappears, its order is not destroyed but rather is enfolded in the glycerine. To develop this analogy further, imagine that a whole series of droplets is enfolded, as follows. The first drop is enfolded with n turns. Next, a second drop is placed in the glycerine, and it is enfolded after another n turns (the first drop is now enfolded 2n turns). Then a third drop is placed in the glycerine, which is enfolded after n turns (the first drop is now enfolded 3n turns, and the second drop 2n turns). Continuing in this way, a whole series of droplets is enfolded in the glycerine. When the direction of rotation is reversed, the drops unfold one at a time, and if this is done quickly enough, the effect is that of a stationary ink drop or "particle" subsisting for a time in the moving fluid. One can also imagine that each successive drop is placed at an adjacent position in the glycerine, so that when the inner cylinder is reversed, the appearance is that of a particle moving along a continuos path. In either case, the sequence of enfolded ink droplets in the glycerine constitutes the implicate order, and the visible droplet that is unfolded at any given moment is the explicate order.

Bohm views the nature of physical reality in analogous fashion to this example. An electron is understood to be a set of enfolded ensembles, which are generally not localized in space. At any given moment, one of these ensembles may be unfolded and localized, and the next moment, this one enfolds and is replaced by another that unfolds. If this process continues in a rapid and regular fashion in which each unfoldment is localized adjacent to the previous one, it gives the appearance of continuous motion of a particle, to which we humans have given the name electron. Yet there is no isolated particle, and its apparent continuous motion is an illusion generated by the rapid and regular sequence of unfoldings (much as a spinning airplane propeller gives the appearance of a solid disk). As Bohm puts it, ". . . fundamentally, the particle is only an abstraction that is manifest to our senses. What is, is always a totality of ensembles, all present together, in an orderly series of stages of enfoldment and unfoldment, which intermingle and inter-penetrate each other in principle throughout the whole of space" (Bohm 1980, 183-184).

Moreover, at any stage of this process, an ensemble may suddenly unfold that is very different from the previous one, which would give the appearance in the explicate order of the electron suddenly jumping discontinuously from one state to another. This offers a new way of understanding what lies behind the well-known quantum mechanical behavior of electrons as they jump discontinuously from one quantum state to another. Indeed, what we call matter is merely an apparent manifestation of the explicate order of the holomovement. This explicate order is the surface appearance of a much greater enfolded or implicate order, most of which is hidden. Contemporary physics and, indeed, most of science deals with explicate orders and structures only, which is why physics has encountered such great difficulty in explaining a variety of phenomena that Bohm would say arise from the implicate order.

The radical implications of Bohm's implicate order take some time to fully grasp, especially for Western minds that have been steeped in the Newtonian-Cartesian paradigm of classical physics that still dominates contemporary science. For example, it might be tempting to assume that the implicate order refers to a subtle level of reality that is secondary and subordinate to the primary explicate order, which we see manifest all around us. However, for Bohm, precisely the opposite is the case: the implicate order is the fundamental and primary reality, albeit invisible. Meanwhile, the explicate order–the vast physical universe we experience–is but a set of "ripples" on the surface of the implicate order. The manifest objects that we regard as comprising ordinary reality are only the unfolded projections of the much deeper, higher dimensional implicate order, which is the fundamental reality. The implicate and explicate orders are interpenetrating in all regions of space-time, and each region enfolds all of existence, that is, everything is enfolded into everything. As Bohm (1980) explains, "[I]n the implicate order the totality of existence is enfolded within each region of space (and time). So, whatever part, element, or aspect we may abstract in thought, this still enfolds the whole and is therefore intrinsically related to the totality from which it has been abstracted. Thus, wholeness permeates all that is being discussed, from the very outset." (p. 172)

Fullness Of Empty Space

Bohm's understanding of physical reality turns the commonplace notion of "empty space" completely on its head. For Bohm, space is not some giant vacuum through which matter moves; space is every bit as real as the matter that moves through it. Space and matter are intimately interconnected. Indeed, calculations of the quantity known as the zero-point energy suggest that a single cubic centimeter of empty space contains more energy than all of the matter in the known universe! From this result, Bohm (1980, 191) concludes that "space, which has so much energy, is full rather than empty." For Bohm, this enormous energy inherent in "empty" space can be viewed as theoretical evidence for the existence of a vast, yet hidden realm such as the implicate order.

Causal Interpretation Of Quantum Theory

The foregoing concepts of holomovement and the implicate order were originally developed by Bohm as a result of his theoretical investigations in quantum theory. Indeed, Bohm's entire life's work was largely shaped by his contributions to quantum theory, which are briefly reviewed here. When Bohm began work in quantum theory, he accepted the "Copenhagen interpretation" of it developed by Niels Bohr, Werner Heisenberg, Wolfgang Pauli, and others. The still-dominant Copenhagen interpretation says two basic things: (1) reality is identical with the totality of observed phenomena (which means reality does not exist in the absence of observation), and (2) quantum mechanics is a complete description of reality; no deeper understanding is possible. In effect, this says that observable phenomena are the whole of reality; and any speculation about a deeper underlying reality is meaningless. Bohr stated it unequivocally: "There is no quantum world. There is only an abstract quantum description" (in Herbert 1985, 17). In this understanding, quantum mechanics provides nothing more or less than a set of statistical rules for connecting observable phenomena.

In 1931, John von Neumann published The Foundations of Quantum Theory, which remains to this day the mathematical bible on that topic. In this book, von Neumann offered a mathematical proof that an ordinary classical reality could not underlie quantum theory. For over twenty years, "von Neumann's proof" stood as a mathematical corroboration of the Copenhagen interpretation. However, in 1952, David Bohm did the impossible and uprooted this "proof" by constructing a model of the electron with classical attributes whose behavior matched the predictions of the quantum theory. In this model, the electron is viewed as an ordinary particle, with one key difference: the electron has access to information about its environment. To derive this model, Bohm began with the Schroedinger equation, which is the central mathematical formula of quantum physics. Using elegant mathematics, Bohm effectively partitioned this equation into two parts, or terms: a classical term that essentially reproduces Newtonian physics, and a nonclassical term that he calls the quantum potential. The classical term treats the electron as an ordinary particle, as in classical physics. The nonclassical quantum potential is a wave-like term that provides information to the electron, linking it to the rest of the universe. The quantum potential is responsible for the well-known wave-particle duality and all the other bizarre phenomena for which quantum theory has become famous. Indeed, the nonlocal character of quantum reality – as implied by Bell's theorem and empirically observed in the renowned experiments of Alain Aspect 2 – may be viewed as plausible evidence for the actual existence of an entity symbolized by the quantum potential.

Bohm was convinced that there is much more going on in quantum mechanics than meets either the eye, the brain, or the laboratory instruments of the physicist. He challenged the prevailing Copenhagen interpretation with his causal interpretation, arguing that as-yet-unknown factors (or "hidden variables") were causing the seemingly inexplicable phenomena observed in quantum experiments. But how and where might these causal factors operate? Bohm pointed out that the smallest detectable distance in physical experiments is about 10-17 centimeters, (cm), whereas the smallest distance beyond which space no longer has any meaning is an extremely tiny 10-33 cm. This leaves an unknown realm that spans sixteen orders of magnitude in relative size, which is comparable to the size difference between our ordinary macroscopic world and the smallest detectable physical distance [10-17 cm]. Having no empirical knowledge of this realm, we cannot dismiss the possibility that causal factors could be operative in this realm.

The key feature of the causal interpretation is the quantum potential, which is a wave-like information field that provides a kind of guidance to the electron. Bohm invokes the analogy of an airliner that changes its course in response to navigational radio signals. The radio waves do not and cannot provide the energy required to change course; rather they provide active information to which the airliner responds by changing course under its own power. The electron responds in an analogous manner to the quantum potential. This could explain the notorious mystery of the "collapse" of the wave function, which occurs as a seemingly random event in the laboratory and is taken by the Copenhagen interpretation to mean that reality does not exist until observed. The Schroedinger wave function describes an infinity of possible outcomes, and the information provided by the quantum potential could cause the electron to "choose" one outcome over all the others. Hence, information alone could cause the "collapse" of an infinity of possibilities into a single manifestation. This is reminiscent of Gregory Bateson's (1972, 382-384) description of fertilization, in which the unfertilized frog's egg contains an infinity of unmanifest potentialities, and the fertilizing sperm provides information that "collapses" the egg's vast potentiality into a single manifest embryo.

Bohm rigorously demonstrated that the causal interpretation predicts physical results identical to those predicted by the Copenhagen interpretation, but with a very different understanding of the underlying deep structure. For example, he shows mathematically that the well-known Heisenberg uncertainty principle may be a crude description of the average statistical behaviour of causal variables, and that Planck's "constant" may not be constant over very small intervals of time or space. Hence, the uncertainty principle may not be an absolute limit on the precision of measurement, as generally believed, but could rather be an expression of the incomplete degree of self-determination that characterizes all quantum mechanical entities. In other words, the uncertainty principle may be a limit that is imposed by our ignorance of causal variables.

The notion of a "potential" is commonplace in physics; for example, the gravitational potential of the Earth tells about the potential energy available at each point in the gravitational field. However, the quantum potential differs in that it has no known physical source, which is one reason that physicists object to it. Even more unacceptable, the action of the quantum potential depends only on its form and not on its intensity, which means that its effect does not diminish with increasing separation in space or time. The form of the quantum potential gives information that is communicated instantaneously, which appears to violate Einstein's Limit of the speed of light for travel of signals. Thus, the quantum potential could be seen as providing information from a meta-physical realm, in the sense that it is beyond ordinary space and time altogether. Though Bohm did not emphasize this aspect in his early work during the 1950s, it became evident later in his concept of the implicate order. Indeed, the theoretical impetus for the implicate order was the quantum potential, which is a mathematical version of the implicate order in the Schroedinger equation.

ORDER AND RANDOMNESS

An inquiry into the nature of order was a central theme that persisted throughout David Bohm's work. To understand why Bohm undertook a study of order, it is important to step back a moment and survey the evolution of his thinking.

Evolution Of Bohm's Thinking

Bohm began with the troubling concern that the two pillars of modern physics–quantum mechanics and relativity theory–actually contradict each other. Moreover, this contradiction is not just in minor details but is very fundamental, because quantum mechanics requires reality to be discontinuous, noncausal, and nonlocal, whereas relativity theory requires reality to be continuous, causal, and local. This discrepancy can be patched up in a few cases using mathematical "renormalization" techniques, but this approach introduces an infinite number of arbitrary features into the theory that, Bohm points out, are reminiscent of the epicycles used to patch up the crumbling theory of Ptolmaic astronomy. Hence, contrary to widespread understanding even among scientists, the "new physics" is self-contradictory at its foundation and is far from being a finished new model of reality. Bohm was further troubled by the fact that many leading physicists did not pay sufficient attention to this discrepancy.

Seeking a resolution of this dilemma, Bohm inquired into what the two contradictory theories of modern physics have in common. What he found was undivided wholeness. Bohm was therefore led to take wholeness very seriously, and, indeed, wholeness became the foundation of his major contributions to physics, as well as his distinctive epistemological style of scientific inquiry. In this respect, Bohm's developmental process was similar to Einstein's in creating relativity theory: Einstein took seriously the experimental observation that the speed of light is the same in all reference frames. This–when coupled with the premise that the laws of physics should be the same in all reference frames–required that space and time could no longer be absolute; hence came the theory of relativity. No one before Einstein had been willing to contemplate something so radical.

Bohm's postulate of undivided wholeness is equally radical, but for a different reason: it questions the prevailing assumptions about order and fragmentation. Just as Einstein was the first physicist to seriously question our understanding of space and time, Bohm is the first physicist to seriously question our understanding of order. The implications are far reaching, because the very essence of science is a quest for natural laws of general applicability, and the sine qua non for such laws is the existence of natural order. Hence, to inquire into the nature of order is to inquire into the foundations of science itself.

In his characteristic way, Bohm went well beyond the bounds of physics in this quest. During the 1960s, he made a systematic inquiry into the nature and function of order in art, and he maintained a seven-year correspondence with American artist Charles Biederman. His correspondence with Biederman focused in particular on order in the paintings of Monet and Cezanne, and this was the seed for the insights described in the next paragraph. Bohm concluded at the time that the order in a painting is equivalent to the order in quantum theory, to which he gave the name the implicate order.

Topology Of Order

Bohm's contributions on order are complex and sophisticated, and they are worthy of thorough study that goes quite beyond what can be included here. Nevertheless, even a cursory glimpse of his thinking is very worthwhile. Bohm proposed that through our perceptions of similarities and differences, we create categories that are the precursors to order. For example, because some creatures transport themselves through air while others do so through water, the categories of birds and fish are created. Each of these categories is refined further, based on perception of finer differences. So we create the categories of sparrows, crows, hawks, eagles, and so on, as well as the categories of minnows, trout, salmon, and sharks. Now observe that the difference between a minnow and a trout is similar to the difference between a sparrow and an eagle (being in this case the difference of relative size). This introduces a notion that Bohm calls similar differences, which can be used to define an order that cuts across various categories of experience. A striking example would be Helen Keller's legendary flash of insight, when she suddenly recognized the essential similarity of different experiences of water.

A different kind of order could be defined by considering, for example, the similarity between a young bird and a young fish, which is different from the similarity between an aging bird and an aging fish. This observation defines an order in terms of different similarities. These are simple examples of concepts that Bohm used to develop a sophisticated topology of order in physics. For example, Bohm showed that Newtonian mechanics is encompassed within the definition of order through similar differences, and Newton's legendary tale about the apple and the moon was essentially a perception that the order of similar differences in the motion of the falling apple is the same as the order of similar differences in the orbit of the moon. Hence, Newton's central insight was one of perceiving a unity of order underlying the outward manifestation of two seemingly unrelated dynamical systems.

In addition the above concepts, Bohm developed a way to measure the complexity of order. To illustrate this with the simplest of examples, consider the infinite sequence of digits 2525252525. . . This sequence is said to have order of second degree, because two items of information (the digits 2 and 5) are required to fully specify the sequence. By the same token, the sequence 264926492649. . . has order of fourth degree, because four digits are required to specify it (namely, 2, 6, 4, 9). Now consider the sequence 601324897. . . What is its order? This is difficult to say. At first glance, it appears to be an arbitrary sequence of digits because there is no discernible order. However, as the sequence continues, we might discover that it is really the following sequence: 601324897601324897601324897. . . in which case it has ninth degree, because the first nine digits are repeated forever. Or, we might find out that it is a sequence of hundredth degree, or millionth degree. Or, the sequence might never exhibit any discernible order whatever, in which case we say it is a sequence of infinite degree. Such a degree we usually think of as a random sequence. In any case, notice that we must know the context to determine the order of the sequence.

Randomness Dependent On Context

The foregoing example hints at a much deeper insight that Bohm developed in a very general context: randomness is not an intrinsic property of the order of a system, but rather randomness depends on context.(3) This is a subtle but very important point, which is likely to have powerful consequences in science for decades to come. An example will illustrate the idea. Consider a "random number generator," which is a type of computer program that generates a sequence of digits that appears to be random. If such a program is left running day and night, it will generate a sequence that has an order of extremely high degree (or practically "infinite"). Such computer programs work in different ways, but they all share an important characteristic: the process used to generate the sequence is a simple deterministic process.(4) If the program is run again with the same starting number, it will produce exactly the same sequence. Hence, the program that generates this sequence has an order of very low degree. Now comes the essential point. In the context of the computer program, the succession of numbers is determined by a simple order of low degree and, therefore, the order in the resulting numbers is also of the same low degree–which is far from random. However, in a narrower context that includes only the numbers themselves but not the computer program–that is, not the "meta" level–the numbers cannot be distinguished from a purely random sequence, and so the order of the numbers is essentially random.

From this, it follows that randomness depends on context, a result that Bohm demonstrated consistently in many examples throughout science. Randomness has played an essentially ontological role in science, being deemed intrinsic to certain natural processes. However, Bohm's findings imply that randomness may vanish whenever the context is deepened or broadened, meaning that randomness can no longer be viewed as fundamental. Bohm's insights into randomness and order in science are summarized in the following statements (Bohm and Peat 1987). "Randomness is... assumed to be a fundamental but inexplicable and unanalyzable feature of nature, and indeed ultimately of all existence. . . (p. 134) [However,] what is randomness in one context may reveal itself as simple orders of necessity in another broader context (p.133) It should therefore be clear how important it is to be open to fundamentally new notions of general order, if science is not to be blind to the very important but complex and subtle orders that escape the coarse mesh of the "net" on current ways of thinking. (p. 136)

Order In Science

The implications of this are potentially very far reaching for all of science. The new field of chaos theory has rigorously demonstrated that in virtually all nonlinear deterministic systems (which characterize most scientific models of physical processes), there is a domain in which the system behaves as if it were random, even though it is actually deterministic. The epistemological implications of this are sweeping: in any discipline of science, when scientists describe the behavior of a natural system as random, this label may not describe the natural system at all, but rather their degree of understanding of that system–which could be complete ignorance. Random empirical data provide no guarantee that the underlying natural process being investigated is itself random. Thus, while "randomness" may usefully characterize the empirical observations of the natural process, this reveals little about the actual nature of the process. Hidden orders or subtle variables may be operating at a level that is beyond the ability of current instruments or concepts to detect. The far-reaching implications of this are evident when one considers, for example, the possibility that the "random mutation" that underpins Darwin's theory of natural selection may soon be regarded as just one arbitrary hypothesis among many. The observed randomness of biological mutations gives no assurance that unknown subtle processes are not operative–hidden beyond the veil of today's empirical science. Such unknown forces could include such "taboo" possibilities as teleological factors, divine design, Sheldrake's morphogenetic fields, and so on.

Bohm's conclusion about order in science is unequivocal and sweeping: the prevailing mechanistic order in science must be dropped. Mainstream physics – from Newton's laws to the most advanced contemporary quantum relativistic field theory – all utilize the same mechanistic order, symbolized by the Cartesian coordinate system. This reflects a particular mechanistic order that has characterized physics for literally centuries, and it is this order that Bohm challenges directly. Science must open itself to far more sophisticated and subtle forms of order, including what Bohm calls generative orders, which are orders that generate structure. The implicate order is perhaps the most important example of a generative order.

DIALOGUES WITH KRISHNAMURTI

In any authentic scientific quest, obstacles of tremendous challenge are confronted periodically that make it very difficult to see how to proceed further. Indeed, if it were otherwise, great science would be much more prevalent than it is. Excruciating trials and tribulations characterize these junctures, which occur all the more frequently when working at the foundational levels of science (rather than with downstream corollaries and theorems, which occupy the time of most scientists). When Bohm encountered such obstacles, he responded in a way that is unusual for scientists, and especially rare among physicists: Bohm carried his quest beyond not only physics but beyond the bounds of science altogether.

Bohm’s greatness is due in significant measure to his frequent habit of carrying his burning questions well beyond science and deep into other epistemological realms, leaving behind everything he knew in the search for new clues and insights. In so doing, Bohm exemplified his commitment to wholeness, not in his theories, but in his epistemology.

The most significant example of this process was Bohm’s extensive dialogues with the Indian spiritual master and mystic, J. Krishnamurti. Bohm was first exposed to Krishnamurti’s teaching when his wife, Saral, brought home to him one of Krishnamurti’s books from the library because she noticed that it centered on the observer/observed relationship, which is so crucial in quantum theory. Bohm and Krishnamurti eventually developed a close friendship, and they carried on an intensive dialogue over several years that entailed deep explorations of the ultimate meaning and nature of thought, insight, existence, death, truth, reality, intelligence, and so on.

Truth Beyond Reality

The Bohm-Krishnamurti dialogue set a profound precedent in being one of the first enduring dialogues between a leading Western physicist and a world-renowned Eastern spiritual master. Their discussions probed deeply into various dimensions of human knowledge and experience, including in-depth discussions of the limitations of human thought, the nature of insight and intelligence beyond thought, as well as many other topics such as truth, reality, death, existence, fragmentation, and the future of humanity. In exploring the distinction between truth and reality, for example, some of the jewels of insight that emerged may be summarized as follows (which, in the spirit of Bohm and Krishnamurti themselves, should perhaps be read slowly and contemplatively to be absorbed). There is a gulf between truth and reality; they are not the same thing. Illusion and falsehood are certainly part of reality, but they are not part of truth. Truth includes all that is; it is one. Reality is conditioned and multiple. Truth is beyond reality; it comprehends reality, but not vice versa. Reality is everything; truth is no-thingness. We need truth, but our minds are occupied with reality. We seek security in reality, but authentic security comes only in complete nothingness, that is, only in truth. The seed of truth is a mystery that thought cannot encompass; it is beyond reality.

Such insights are characteristic of Krishnamurti’s teachings. Indeed, perhaps the greatest impact of these dialogues on Bohm was a cultivated understanding of the limitations of human thought, as well as a deep realization of the existence of pure awareness beyond thought, wherein lies the source of all true insight, intelligence, and creativity. Bohm also had a number of meetings with other spiritual masters, most notably the Dalai Lama. The influence of spiritual teachings are apparent in all of Bohm’s later work, and, indeed, they are perhaps particularly significant in his formulation of the superimplicate order, which will be discussed shortly. Bohm’s work in physics is unique in that he built a spiritual foundation into his theories that gives them a profound philosophical and metaphysical significance while rigorously preserving their empirical and scientific basis.

On Dialogue

A highly fruitful outcome of these dialogues was the cultivation of dialogue itself as a path to greater wisdom and learning. Bohm refined dialogue to a creative art, and his teachings have been published in book entitled On Dialogue (1990). Indeed, so influential was his example that several groups have been formed around the world to engage in "Bohmian dialogue," and a Dialogue Project is thriving at the Massachusetts Institute of Technology. 5 Bohm believed that the fragmentation and breakdown in communication in our culture are reinforced by our ways of thinking, and that through free-form dialogue it is possible to reestablish a genuine and creative collective consciousness. Dialogue differs from ordinary conversation, where people generally hold a point of view that they feel compelled to defend.

In dialogue, participants give serious consideration to views that may differ substantially from their own, and they are willing to hold many conflicting possibilities in their minds simultaneously and to accept what is, however uncomfortable. By this means, people in dialogue can together create the possibility for new insights and creativity to emerge, which would not be possible by merely thinking on their own. To give a brief example Bohm's dialogue with Krishnamurti, the following extract (Krishnamurti and Bohm 1985, 149-53) on the holomovement and death seems particularly appropriate, in view of Bohm's recent passing (as well as Krishnamurti's in 1986).

K: What is movement, apart from movement from here to there, apart from time–is there any other movement?
B: Yes.

K: There is. . . is there a movement which in itself has no division? . . . Would you say it has no end, no beginning?
B: Yes. . . Can one say that movement has no form?

K: No form–all that. I want to go a little further. What I am asking is, we said that when you have stated there is no division, this means no division in movement.
B: It flows without division, you see.

K: Yes, it is a movement in which there is no division. Do I capture the significance of that? Do I understand the depth of that statement? . . . I am trying to see if that movement is surrounding man?
B: Yes, enveloping.

K: I want to get at this. I am concerned with mankind, humanity, which is me. . . I have captured a statement which seems so absolutely true–that there is no division. Which means that there is no action which is divisive.
B: Yes.

K: I see that. And I also ask, is that movement without time, et cetera. It seems that it is the world, you follow?
B: The universe.

K: The universe, the cosmos, the whole.
B: The totality.

K: Totality. Isn't there a statement in the Jewish world, "Only God can say I am."
B: Well, that's the way the language is built. It is not necessary to state it.

K: No, I understand. You follow what I am trying to get at?
B: Yes, that only this movement is.

K: Can the mind be of this movement? Because that is timeless, therefore deathless.
B: Yes, the movement is without death; in so far as the mind takes part in that, it is the same.

K: You understand what 1 am saying?
B: Yes. But what dies when the individual dies?

K: That has no meaning, because once I have understood there is no division.
B: . . . then it is not important.

K: Death has no meaning.
B: It still has a meaning in some other context.

K: Oh, the ending of the body; that's totally trivial. But you understand? I want to capture the significance of the statement that there is no division, it has broken the spell of my darkness, and I see that there is a movement, and that's all. Which means death has very little meaning.
B: Yes.

K: You have abolished totally the fear of death.
B: Yes, I understand that when the mind is partaking in that movement, then the mind is that movement.

K: Yes, I would say that everything is. . . . One can never say then, "I am immortal." It is so childish.
B: Yes, that's the division.

K: Or, "I am seeking immortality." Or "I am becoming." We have wiped away the whole sense of moving in darkness. . .
B: Just going back to what we were saying a few days ago: we said we have the emptiness, the universal mind, and then the ground is beyond that.

K: Would you say beyond that is this movement?
B: Yes. The mind emerges from the movement as a ground, and falls back to the ground; that is what we are saying.

K: Yes, that's right. Mind emerges from the movement.
B: And it dies back into the movement.

K: That's right. It has its being in the movement.
B: Yes, and matter also.

K: Quite. So what I want to get at is, I am a human being faced with this ending and beginning. [This] abolishes that.
B: Yes, it is not fundamental.

K: It is not fundamental. One of the greatest fears of life, which is death, has been removed.
B: Yes.

SUPERIMPLICATE ORDER AND BEYOND

The hologram analogy gives only a limited view of the implicate order because it is a metaphor derived from a classical treatment of the transformations within a light wave. To delve more deeply into the implicate order, Bohm developed a causal interpretation of the quantum field theory.

Superquantum Potential

Quantum field theory is the most general and sophisticated form of quantum physics. The primary physical reality is assumed to be a continuous field, and the discrete, particle-like quanta are viewed as mere epiphenomena. Hence, rather than taking the particle as the starting point, the field is taken as the fundamental reality. In parallel, rather than postulating a quantum potential that acts on the particle, Bohm postulates a superquantum potential that acts on the field. This superquantum potential is far more subtle and complex than the quantum potential, yet its basic principles are similar, and its net effect is to modify the field equations so as to make them nonlinear and nonlocal. Hence, the superquantum potential is responsible for the perception of discrete quanta because" it can "sweep" energy from the entire field into a tiny region of space, thereby creating the appearance of a "particle," or of a quantum jump in a particle's energy state. In this way, a continuous field can behave as if it were made up of discrete elementary particles. This differs from the particle model described earlier, in which wave-particle duality was explained as the effect of the quantum potential on the particle. Here, wave-particle duality is understood to be an effect of the superquantum potential on the continuous field.

Definition: EPIPHENOMENA: noun: a secondary symptom, which may occur simultaneously with a disease etc. but is not regarded as its cause or result. Source Oxford Dictionary. (Alex Paterson)

Superimplicate Order

This leads to the most general formulation of Bohm's theory, presented in his 1987 book Science, Order, and Creativity (co-authored by David Peat). Bohm proposed that above and beyond the implicate order, there is also a superimplicate order. In the example of quantum field theory just described, the implicate order is just the field itself, and the superimplicate order is the superquantum potential, which is a much more subtle and complex implicate order than the field. Once again, the explicate order is merely the set of "ripples" and discontinuities in the field that our instruments can observe, which are created by the effect of the superimplicate order on the implicate order. In this understanding, the particle is no longer a basic concept, since the primary reality is the implicate and superimplicate orders.

With the superimplicate order, Bohm reached his final and deepest interpretation of the solution of the Schroedinger equation for a particle. He had begun in his youth with the Copenhagen interpretation, in which the particle does not exist, which he had always found unsatisfactory. Then in his initial formulation of the implicate order, he supposed that the particle does exist more or less as an ordinary particle, but that it behaves in a strange manner because it receives information through the quantum potential, which is a wave-like information field independent of space and time. As Bohm put it, "The electron, in so far as it responds to a meaning in its environment, is observing the environment. It is doing exactly what human beings are doing" (in Weber 1986, 69).

Then finally, in the superimplicate order, the particle does not exist except as an abstraction in our minds or an epiphenomenon perceived by our instruments. What exists is the holomovement, which in this case consists of the continuously changing quantum field (or implicate order), and the superquantum potential (or superimplicate order). The "particle" (explicate order) is merely a discontinuous ripple effect created by the effect of the superquantum potential on the field.

Naturally, given a second implicate order, it is easy to imagine third, fourth, and higher implicate orders. Indeed, Bohm suggested that a whole hierarchy of superimplicate orders might be envisioned, although their effects would be increasingly subtle and therefore difficult to observe or analyze. These higher implicate orders would feed back to the original explicate order, which could produce complex dynamics over time, allowing creativity and novelty to unfold.

To clarify these concepts with an analogy, consider a video game. The first implicate order corresponds to the screen, which is capable of producing an infinite variety of explicate forms or images. The images on the screen, which constitute the explicate order, can be regarded as manifestations of' the first implicate order. The second implicate order corresponds to the computer, which provides the information that organizes the various forms in the screen, or first implicate order. Finally, the player of the game represents a third implicate order, whose actions and inputs organize the second implicate order. This creates a closed loop, and creative possibilities can emerge over time.

Eternal Order

In sum, Bohm's model of reality consists of a dynamic holomovement that has three basic realms or levels of manifestation: the explicate order, the implicate order, and the superimplicate order–with the latter two realms constituting the bulk of reality. The possible forms for the superimplicate order (or orders) may be highly complex, subtle, and difficult to conceive in terms of ordinary concepts. For example, Bohm speaks of an eternal order, which is a superimplicate order that lies beyond the domain of time. As such, the eternal order is neither static nor everlasting but is outside of time altogether, and it is ever creative. As this creativity filters down to lower implicate orders, it tends to become manifest in time; that is, it enters a temporal order. In Bohm's words, "the eternal order is not properly to be regarded as static, but rather as eternally fresh and new. As attention goes to the consideration of succession, however, it begins to get directed toward the temporal or secular order" (Bohm and Peat 1987, 225).

The quantum potential, the superquantum potential, the implicate order, and superimplicate orders are all names given to realms that are invisible to ordinary perception, yet for Bohm, they constitute the true structure of reality. For Bohm, the holomovement is the nature of reality, and the implicate order and superimplicate order are its primary structural features, with the explicate order being the surface appearance. Superimplicate orders may be involved in innumerable physical and natural processes. In evolution, for example, superimplicate orders could guide the emergence of a bird, which must not only develop wings but aerodynamically adapted feathers, appropriate musculature, shifted center of gravity, lighter bones and appropriate changes in metabolism–all at the same time. Otherwise, any one of these changes by itself would likely decrease chances of survival. Observe that the superimplicate order appears to be analogous to archetypes or to Sheldrake's morphogenetic fields. All of these terms are just labels for subtle orders or forces that remain hidden to empirical science, and hence they are resisted by mainstream scientists, sometimes vehemently. However, just because they have not been directly observed does not mean that they do not exist. In his postulate of the implicate order, Bohm clearly demonstrates how such realms could exist and be very fundamental, while being missed altogether by mainstream science in its focus on the explicate order only.

Thought And Meaning

Bohm inquired deeply on many levels and subjects that went quite beyond his field of science. He developed a poignant critique of thought, which was influenced by his association with Krishnamurti, and he also came to believe that meaning is a fundamental element of existence. These ideas are briefly explored below, mostly in his own words.

Critique of Thought

Bohm was unusual among scientists in questioning the primary epistemological engine for all scientific inquiry: human thought itself. He stressed that thought creates structures and then pretends they are objective realities independent of thought. Thus our "objective reality" is largely a construct of thought, and not recognizing this leads us to endless circles of self-deception–in science as well as in life in general. Indeed, Bohm felt that much personal and collective suffering has its roots in human thought. In his words (1982), "[T]hought is really a very tiny little thing. But thought forms a world of its own in which it is everything. . . It reifies itself and imagines there's nothing else but what it can think about itself and what it thinks about. Therefore thought will now take the words, "the nonmanifest" and form the idea of the nonmanifest; and therefore, thought thinks the manifest plus the nonmanifest together make up the whole, and that this whole thought is now a step beyond thought, you see. But in fact, it isn't. This nonmanifest (that thought imagines) is still the manifest, by definition, because to imagine is also a form of thought." (p. 63) For this reason, Bohm felt that it is vital to go beyond thought, for which meditation is one possible path. "[M]editation would even bring us out of all [the difficulties] we've been talking about. . . [S]omewhere we've got to leave thought behind, and come to this emptiness of manifest thought altogether. . . In other words, meditation actually transforms the mind. It transforms consciousness." (Pp. 103-104)

Definition: EPISTEMOLOGY: noun: The theory of knowledge, especially with regard to its methods and validation. adj: epistemological. Source: Oxford Dictionary. (Alex Paterson)

Ontology of Meaning

As Bohm's work matured, he placed increasing emphasis on the importance of meaning, and he came to regard matter, energy, and meaning as three major constituents of our existence (in Rinpoche 1992, 354). "From the point of view of the implicate order, energy and matter are imbued with a certain kind of significance which gives form to their over-all activity and to the matter which arises in that activity. The energy of mind and of the material substance of the brain are also imbued with a kind of significance which gives form to their over-all activity. So quite generally, energy enfolds matter and meaning, while matter enfolds energy and meaning. . . But also meaning enfolds both matter and energy. . . So each of these basic notions enfolds the other two. . . . "This implies, in contrast to the usual view, that meaning is an inherent and essential part of our overall reality, and is not merely a purely abstract and ethereal quality having its existence only in the mind. Or to put it differently, in human life, quite generally, meaning is being." (pp. 90-93).

IMPACT AND IMPLICATIONS OF BOHM'S WORK

Bohm's theories have had a powerful impact in many fields ranging from psychology to brain physiology to philosophy. A brief review of these implications are given below, beginning with the curious reaction to Bohm's ideas in his own field of physics.

Cool Reception in Physics

Bohm's theories never received a full, serious reading in the mainstream physics community, to his considerable disappointment. His work met with reactions ranging from lack of understanding or interest to dismissal or even suspicion. There are several reasons for this, which tell much about the state of science today.

Bohm lamented that physics is primarily concerned with prediction and control, rather than with truth. Because his theories offered little to enhance prediction and control, many scientists were simply not interested in them. Indeed, Bohm's interpretation of quantum mechanics was criticized because it did not yield results that differ from orthodox quantum theory, which makes it difficult to test against conventional interpretations. In this sense, Bohm's theory was charged with failing to satisfy Popper's (1969) falsifiability criterion for a legitimate scientific theory. (defn: falsifiability: capable of being falsified. source Websters) Yet this very criticism could be leveled at any of the interpretations of quantum theory. There are at least eight different interpretations, each of which is consistent with the Schroedinger wave equation and the experimental results of quantum mechanics. 6 Which of these theories is "correct," if any, is not a question that can be settled by resorting to the experimental evidence. Indeed, as Bohm points out, "all the available interpretations of quantum theory, and indeed of any other physical theory, depend fundamentally on implicit or explicit philosophical assumptions, as well as on assumptions that arise in countless other ways from beyond the field of physics. (Bohm and Peat 1987, 102).

Thus there is no scientific reason for preferring one interpretation over the others. As John A. Wheeler put it, "No theory of physics that deals only with physics will ever explain physics." (in Wilber 1982, 183).

Penchant for Parsimony

Another objection to Bohm's ideas is that they are not "parsimonious"; that is, they introduce unnecessary concepts like wholeness and holomovement, which cannot be observed in the laboratory. Bohm responds that rigid adherence to Occam's razor is over-restrictive and could obscure a deeper reality that may underlie laboratory observations. To illustrate his point, Bohm considers the example of a fish in an aquarium that is observed by means of two television cameras at right angles to each other. The observed images on the two television monitors give the appearance of distinct, correlated entities, but these observations are not the reality; rather they are merely different aspects of a deeper underlying unity–in this case, the fish itself.

There are some curious ironies in this objection to Bohm. Surely it is more parsimonious to assume that reality is a single, undivided whole until proven fragmented, rather than the other way around. Yet today's physics takes reality to be fragmented into some 10 to the power of eighty extremely tiny particles, each of which is further divided into untold numbers of elementary particles. This can be considered "parsimonious" only because the majority of physicists are committed to an extreme form of what could be called instrumental positivism, which says, in effect: Reality is that which is observed and measured by laboratory instruments; what cannot be measured does not exist. Even more ironic, despite the mandatory allegiance to fragmentation required of all practicing physicists, not one of them actually believes it–else they would not search in earnest for the Grand Unified Theory. In any case, were they to seriously contemplate Bohm's perspective, they might discover that they have been striving to unite what was never really separate, and that Occam's razor argues for Bohm's understanding of undivided wholeness, rather than against it.

MATTER AND CONSCIOUSNESS

When Bohm's Wholeness and the Implicate Order was published in 1980, the "holographic model" quickly became a lively topic of discussion and debate among new paradigm thinkers. One of the most enduring issues was the implications of Bohm's theories for the relationship between matter and consciousness. Do mind and body correspond to the implicate and explicate orders? Can consciousness tap directly into the implicate order?

Bohm's own reflection on these questions seems to have evolved over time. Early on, in response to Wigner and others who proposed that consciousness should be included in quantum theory, Bohm said that his aim was to describe the quantum potential without bringing in the conscious observer in any fundamental role. Later, Bohm came to believe that material and informational processes are inextricably intertwined together in all things, and he used the term soma-significance to refer to this intrinsic interpenetration. As he explains (in Bohm and Peat 1987, 185-186 and Weber 1986, 215), "Consciousness is much more of the implicate order than is matter. . . Yet at a deeper level [matter and consciousness] are actually inseparable and interwoven, just as in the computer game the player and the screen are united by participation in common loops. In this view, mind and matter are two aspects of one whole and no more separable than are form and content. "Deep down the consciousness of mankind is one. This is a virtual certainty because even in the vacuum matter is one; and if we don't see this, it's because we are blinding ourselves to it."

Materialism and Idealism

A corollary of this view is that the philosophical distinction between materialism and idealism disappears (in Weber 1986): "The question is whether matter is rather crude and mechanical or whether it gets more and more subtle and becomes indistinguishable from what people have called mind. . . [In] idealism form is primary. One suggestion is that the form enters into an energy which gives rise to a determinate activity and eventually to a determinate structure of matter. . . I'll extend Gregory Bateson's definition of information to say that it's a difference of form that makes a difference of content and meaning. This form is carried out as meaning and energy. If you read a printed page, which is a form, the meaning gives rise to an energy from which you act. Therefore we could say that the distinction of materialism and idealism is eroded, it gradually dissolves. . . "Pure idealism would reduce matter to an aspect of mind. Hegel was an example of that. Pure materialism would reduce mind to an aspect of matter, and of course that's what we see in a great deal of modern science. My view does not attempt to reduce one to the other any more than one would attempt to reduce form to content. . . Every content is a form and every form is at the same time a content." (pp. 150-51)

Applications of Holographic Model

Bohm's holographic metaphor has found fruitful application in brain physiology and human consciousness. Neurosurgeon Karl Pribram developed a model of the brain based on holographic principles (1971); Pribram was trying to understand various features of the brain, especially the observed result that the function of memory storage is not localized in the brain. Pribram's controversial holographic model accounts for seemingly mysterious properties of the brain such as the vast storage capacity, the imaging capability of the sensory system, and certain features of associative recall. Another striking application of the holographic model is in the spectrum of human consciousness. Psychiatrist Stanislav Grof (1985, 1988) has developed a cartography of human consciousness that summarizes his extensive research into nonordinary states of consciousness. He has noted a close correspondence between the holomovement and his research findings. More than thirty years of clinical research and observation have led Grof to the viewpoint that "each of us is everything." meaning that every human being has potential access to all forms of consciousness (Grof 1990). His data provide a kind of phenomenological evidence for a holographic model of consciousness.

SCIENCE AND SPIRIT

Thomas Kuhn has eloquently shown that scientists' preference for one paradigm over another is determined by a host of nonscientific, nonempirical factors. As noted earlier, Bohm also points out that there is no scientific evidence that argues for the dominant fragmented scientific world view over Bohm's hypothesis of undivided wholeness. However, while scientific evidence offers no help in this regard, other forms of evidence may, indeed, shed some light on the matter. Mystical and spiritual teachings down through the ages have spoken about the fundamental interconnectedness of all things and that the microcosm somehow contains the macrocosm. A beautiful and legendary image of this is the "jeweled net of Indra" in the Avatamsaka Sutra, in which the universe is represented as an infinite network of pearls, each of which reflects all the others. Fa-Tsang, the founder of Hua-yen Buddhism in the seventh century, represented the relation of the "One to the many" by placing a candle in the center of a room full of mirrors, and he represented the relation of the "many to the One" by placing a polished crystal next to the candle. While these and other images do not constitute experimental evidence of the kind that science considers admissible, they do represent a consistent body of "experiential evidence" from a long line of deeply perceptive traditions down through the ages. So if we broaden the permissible epistemology beyond the bounds of science, we find ample precedent for a unitive holographic understanding of reality. From this perspective, there is, indeed, evidence for preferring Bohm's holomovement over other views of reality that dominate science today.

Buddhism and Physics

The Tibetan Master Sogyal Rinpoche (1992) has noted striking parallels between Bohm's model and the three kayas in Buddhist ontology.

"Could this possibly suggest that the role of meaning, as [Bohm] explains it, is somehow analogous to the Dharmakaya, that endlessly fertile, unconditioned totality from which all things rise? The work of energy, through which meaning and matter act upon one another, has a certain affinity to the Sambhogakaya, the spontaneous, constant springing forth of energy out of the ground of emptiness, and the creation of matter, in David Bohm's vision, has resemblances to the Nirmanakaya, the continuous crystallization of that energy into form and manifestation. . . The deepest parallel between David Bohm's ideas and the bardo teachings is that they both spring from a vision of wholeness." (P. 354) Bohm (in Weber 1986) himself sounds indistinguishable from a spiritual master at times: "When we come to light, we are coming to the fundamental activity in which existence has its ground. . . Light is the potential of everything. . . This ocean of energy could be thought of as an ocean of light" (155).

Of course we must remember that mystical experience ultimately transcends intellectual experience, theories, and insights. The concepts and descriptions of superimplicate order and the holomovement may sound similar in some ways to descriptions of mystical experience. However, these correlations in language court the danger of equating concepts relevant to mystical experience with the experience itself. Ken Wilber (1982) cautions against this with his inimitable wit: "To be sure, there are similarities of language–the holographic blur ("no space, no time") sounds like a mystical state. It also sounds like passing out" (180).

The implicate order has been likened to an ultimate realm beyond matter and thought that is the wellspring of true knowledge and wisdom. Bohm and Peat (1987) emphasize that the suspension of "explicate" activity is essentially the same in Taoism, Yoga, Buddhism, and Krishnamurti's teachings (255-57). From an ontological point of view, the superimplicate orders may be seen as symbolic of a realm of Mystery, the Unknown, the Unseen, as referred to in the world's spiritual and mystical traditions.

When Krishnamurti asked Bohm what is the point of the mystery, Bohm (Krishnamurti and Bohm 1987) gave the following succinct reply:

"Of the mystery? I think you could see it like this: that if you look into the field of thought and reason and so on, you finally see it has no clear foundation. Therefore, you see that "what is" must be beyond that. 'What is' is the mystery." (p. 46)

BOHM'S LEGACY

David Bohm has shown that physics is rigorously consistent with a radical reinterpretation of reality that goes quite beyond the revolutionary new physics of the early twentieth century. Contemporary scientists may ignore Bohm's work (as many have done), but they cannot escape its implications. Bohm approached science as a quest for truth, and, in this spirit, he unpacked and revealed the epistemological foundations of science (in his study of order), and he utilized these insights to conceive a profound ontological hypothesis (the holomovement and implicate orders). This hypothesis is rigorously grounded in the experimental evidence of physics, and as such it is not just a new way of thinking about physics, it is a new physics; that is, it is an entirely new way of understanding the fundamental nature of the physical universe, as glimpsed through the data and laws of physics.

As such, Bohm's world view has profound implications for the whole of science. Prior to Bohm, science had generally regarded the universe as a vast multitude of separate interacting particles. Bohm offers an altogether new view of reality to underpin the entire body of theory and data that we call science. The single most important feature of this reality is "unbroken wholeness in flowing movement." What is remarkable about Bohm's hypothesis is that is it also consistent with spiritual wisdom down through the ages. Moreover, Bohm shows that there is no concrete evidence in science to favor its fragmented world view over the unbroken, flowing holomovement he proposes; it is a matter of individual beliefs and predilections.

Within physics, Bohm has demonstrated that one way to interpret the Schroedinger equation in quantum field theory is to introduce a wave-like information field called the superquantum potential, whose action transcends all of space in a timeless unity. This is not to say that Bohm has discovered God in the Schroedinger equation; it is to say that he has found theoretical precedent within physics for a subtle realm that lies beyond physics, as usually conceived. This does not prove anything, but it does show that physics can be rigorously consistent with the existence of higher realms of truth, order, existence, and eternity.

The great strength of science is that it is rooted in actual experience; the great weakness of contemporary science is that it admits only certain types of experience as legitimate. Bohm responded to this by carrying his quest for knowledge not only deeply into science, but also far beyond science. He did not restrict himself to laboratory data or accepted theoretical methods–though he was master at both. His passion for truth carried him wherever it might possibly find nourishment, and his theories consequently reflect tremendous breadth and depth in accounting for a wide range truths that stem from a diverse spectrum of epistemologies. If the greatness of scientific work can be measured by its depth and general applicability in a multiplicity of fields, then David Bohm is clearly one of greatest physicists of this century.

Bohm was deeply troubled by the suffering in the world, and his vision called for a complete restructuring of our fragmented collective consciousness in a new Renaissance (Bohm and Peat 1987).

"What is needed today is a new surge that is similar to the energy generated during the Renaissance but even deeper and more extensive;. . . the essential need is for a "loosening" of rigidly held intellectual content in the tacit infrastructure of consciousness, along with a "melting" of the "hardness of the heart" on the side of feeling. The "melting" on the emotional side could perhaps be called the beginning of genuine love, while the "loosening" of thought is the beginning of awakening of creative intelligence. The two necessarily go together." (pp. 265, 271)

Genuine love and creative intelligence were, indeed, the hallmarks of David Bohm's life work. Through his mind and heart, he has given us a magnificent gift, which he offers to us in the grace of yet another gift. Bohm cautions us not to take any ideas–including his own–too literally. Indeed, David Bohm (1982) encourages us all to go far beyond theories of any kind.

"This whole construction of the implicate; order is a kind of bridge [that] leads to somewhere beyond. . . However, if you don't cross the bridge and leave it behind, you know, you're always on the bridge. No use being there! The purpose of a bridge is to cross. . . Or, more accurately, we could perhaps think of a pier, leading us out into the ocean and enabling us to dive into the depths. . . [To] linger on the implicate order would then. . . be like the fellow who stays on the pier and never dives into the depths of the ocean." (pp. 103-104)

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Footnotes

1. Einstein's opinions of Bohm's work reported in M. Talbot, The Holographic (Universe (New York: HarperCollins, 1991), 39.

2. For a detailed account, see Nick Herbert, Quantum Reality (New York: Doubleday, 1985).

3. Bohm defines a random order as one having the following three characteristics: (1) it is of infinite degree, (2) it has no significant correlations or stretches of suborder of low degree,

and (3) it has a fairly constant average behavior. David Bohm and David Peat, Science, Order, and Creativity (London: Ark, 1987), 126-27.

4. For example, one such program operates by starting with a given eight-digit number, then multiplying this number by itself, which gives a huge number, and then selecting the middle eight digits. This new eight-digit number is then cycled through the same process, and the result is a sequence of digits that appear to have no order in relation to each other.

5. See W. Isaacs, "Dialogue: The Power of Collective Thinking." Systems Thinker (April) 1993.

6. See, for example, Nick Herbert, Quantum Reality (New York: Doubleday, 1985).

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