THE NON-LOCAL UNIVERSE

THE NEW PHYSICS AND MATTERS OF THE MIND

ROBERT NADEAU AND MENAS KAFATOS

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OXFORD
UNIVERSITY PRESS

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Oxford New York
Athens Auckland Bangkok Bogotá Buenos Aires Calcutta
Cape Town Chennai Dar es Salaam Delhi Florence Hong Kong Istanbul
Karachi Kuala Lumpur Madrid Melbourne Mexico City Mumbai
Nairobi Paris São Paulo Shanghai Singapore Taipei Tokyo Toronto Warsaw

and associated companies in
Berlin Ibadan

First published by Oxford University Press, Inc., 1999
198 Madison Avenue, New York, New York 10016

First issued as an Oxford University Press paperback, 2001

Library of Congress Cataloging-in-Publication Data

Nadeau, Robert, 1944-

The non-local universe: the new physics and matters of the mind /

by Robert Nadeau and Menas Kafatos.

p. cm.

Includes bibliographical references and index.

ISBN 0-19-513256-4 (Cloth)

ISBN 0-19-514408-2 (Pbk.)

1. Quantum theory. 2. Physics—Philosophy. I. Kafatos, Menas C.

II. Title.

QC174.12.N32 1999 530'.01—dc21 99-17062

1 3 5 7 9 10 8 6 4 2

Printed in the United States of America

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INTRODUCTION

This book is the product of a fifteen-year dialogue between a physicist and an historian and philosopher of science. The physicist has demonstrated expertise in computational science, astrophysics, earth systems science, general relativity, and the foundations of quantum theory; the historian and philosopher of science has written widely on the societal impacts of scientific and technological change. The decision to write a book for the general reader was motivated by our conviction that the discovery of nonlocality has more potential to transform our conceptions of the "way things are" than any previous discovery in the history of science. The implications of this discovery extend well beyond the domain of the physical sciences, and the best efforts of large numbers of thoughtful people will be required to understand them.

Perhaps the most startling and potentially revolutionary of these implications in human terms is a new view of the relationship between mind and world that is utterly different from that sanctioned by classical physics. René Descartes, for reasons we will discuss in a moment, was among the first to realize that mind or consciousness in the mechanistic worldview of classical physics appeared to exist in a realm separate and distinct from nature. After Descartes formalized this distinction in his famous dualism, artists and intellectuals in the Western world were increasingly obliged to confront a terrible prospect. The prospect was that the realm of the mental is a self-contained and self-referential island universe with no real or necessary connection with the universe itself.

It is well-known that the problem of the homeless mind has been one of the central features and fundamental preoccupations of Western intellectual life since the seventeenth century. And there is certainly nothing new in the suggestion that the contemporary scientific worldview legitimates an alternate conception of the relationship between mind and world. Numerous writers of New Age books, along with a few well-known New Age gurus, have played fast and loose with the "implications" of the new physics in an attempt to ground the mental in some vague sense of cosmic Oneness. But if this book is ever erroneously placed in the New Age section of a commercial bookstore and purchased by those interested in New Age literature, they will be quite disappointed.

Our proposed new understanding of the relationship between mind and world is framed within the larger context of the history of mathematical physics, the origins and extensions of the classical view of the foundations of scientific knowledge, and the various ways that physicists have attempted to obviate previous challenges to the efficacy of classical epistemology. We will demonstrate why the discovery of nonlocality has forced us to abandon this epistemology and propose an alternate understanding of the actual character of scientific epistemology originally articulated by the Danish physicist Niels Bohr. This discussion will serve as background for understanding a new relationship between parts and wholes in quantum physics, as well as a similar view of that relationship that has emerged in the so-called "new biology" and in recent studies of the evolution of modern humans.

But at the end of this sometimes arduous journey lie two conclusions that should make the trip very worthwhile. First, there is no basis in contemporary physics or biology for believing in the stark Cartesian division between mind and world that some have rather aptly described as "the disease of the Western mind." And second, there is a new basis for dialogue between two cultures that are now badly divided and very much in need of an enlarged sense of common understanding and shared purpose—the cultures of humanists-social scientists and scientists-engineers. For the moment, let us briefly consider the legacy in Western intellectual life of the stark division between mind and world sanctioned by classical physics and formalized by Descartes.

CLASSICAL PHYSICS AND THE LEGACY OF DESCARTES

The first scientific revolution of the seventeenth century freed Western civilization from the paralyzing and demeaning forces of superstition, laid the foundations for rational understanding and control of the processes of nature, and ushered in an era of technological innovation and progress that provided untold benefits for humanity. But as classical physics progressively dissolved the distinction between heaven and earth and united the universe in a shared and communicable frame of knowledge, it presented us with a view of physical reality that was totally alien from the world of everyday life.

Descartes, the father of modern philosophy, rather quickly realized that there was nothing in this view of nature that could explain or provide a foundation for the mental, or for all that we know from direct experience as distinctly human. In a mechanistic universe, he said, there is no privileged place or function for mind, and the separation between mind and matter is absolute. Descartes was also convinced, however, that the immaterial essences that gave form and structure to this universe were coded in geometrical and mathematical ideas, and this insight led him to invent algebraic geometry.

A scientific understanding of these ideas could be derived, said Descartes, with the aid of precise deduction, and he also claimed that the contours of physical reality could be laid out in three-dimensional coordinates. Following the publication of Isaac Newton's *Principia Mathematica* in 1687, reductionism and mathematical modeling became the most powerful tools of modern science. And the dream that the entire physical world could be known and mastered through the extension and refinement of mathematical theory became the central feature and guiding principle of scientific knowledge.

The radical separation between mind and nature formalized by Descartes served over time to allow scientists to concentrate on developing mathematical descriptions of matter as pure mechanisms in the absence of any concerns about its spiritual dimensions or ontological foundations. Meanwhile, attempts to rationalize, reconcile, or eliminate Descartes's stark division between mind and matter became perhaps the most central feature of Western intellectual life.

Philosophers like John Locke, Thomas Hobbes, and David Hume tried to articulate some basis for linking the mathematical describable motions of matter with linguistic representations of external reality in the subjective space of mind. Descartes' countryman Jean-Jacques Rousseau reified nature as the ground of human consciousness in a state of innocence and proclaimed that "Liberty, Equality, Fraternity" are the guiding principles of this consciousness. Rousseau also made god-like the idea of the "general will" of the people to achieve these goals and declared that those who do not conform to this will were social deviants.

The Enlightenment idea of deism, which imaged the universe as a clockwork and God as the *clockmaker*, provided grounds for believing in divine agency at the moment of creation. It also implied, however, that all the creative forces of the universe were exhausted at origins, that the physical substrates of mind were subject to the same natural laws as matter, and that the only means of mediating the gap between mind and matter was pure reason. Traditional Judeo-Christian theism, which had previously been based on both reason and revelation, responded to the challenge of deism by debasing rationality as a test of faith and embracing the idea that the truths of spiritual reality can be known only through divine revelation. This engendered a conflict between reason and revelation that persists to this day. And it also laid the foundation for the fierce competition between the mega-narratives of science and religion as frame tales for mediating the relation between mind and matter and the manner in which the special character of each should be ultimately defined.

Rousseau's attempt to posit a ground for human consciousness by reifying nature was revived in a somewhat different form by the nineteenth-century Romantics in Germany, England, and the United States. Goethe and Friedrich Schelling proposed a natural philosophy premised on ontological monism (the idea that God, man, and nature are grounded in an indivisible spiritual Oneness) and argued for the reconciliation of mind and matter with an appeal to sentiment, mystical awareness, and quasi-scientific musings. In Goethe's attempt to wed mind and matter, nature becomes a mindful agency that "loves illusion," "shrouds man in mist," "presses him to her heart," and punishes those who fail to see the "light." Schelling, in his version of cosmic unity, argued that scientific facts were at best partial truths and that the mindful creative spirit that unites mind and matter is progressively moving toward self-realization and undivided wholeness.

The British version of Romanticism, articulated by figures like William Wordsworth and Samuel Taylor Coleridge, placed more emphasis on the primacy of the imagination and the importance of rebellion and heroic vision as the grounds for freedom. As Wordsworth put it, communion with the "incommunicable powers" of the "immortal sea" empowers the mind to release itself from all the material constraints of the laws of nature. The founders of American transcendentalism, Ralph Waldo Emerson and Henry David Thoreau, articulated a version of Romanticism that was more commensurate with the ideals of American democracy.

The Americans envisioned a unified spiritual reality that manifested itself as a personal ethos that sanctioned radical individualism and bred aversion to the emergent materialism of the Jacksonian era. They were also more inclined than their European counterparts, as the examples of Thoreau and Whitman attest, to embrace scientific descriptions of nature. But the Americans also dissolved the distinction between mind and matter with an appeal to an ontological monism and alleged that mind could free itself from all the constraints of matter in states of mystical awareness.

Since scientists during the nineteenth century were preoccupied with uncovering the workings of external reality and virtually nothing was known about the physical substrates of human consciousness, the business of examining the dynamics and structure of mind became the province of social scientists and humanists. Adolphe Quételet proposed a "social physics" that could serve as the basis for a new discipline called sociology, and his contemporary Auguste Comte concluded that a true scientific understanding of the social reality was quite inevitable. Mind, in the view of these figures, was a separate and distinct mechanism subject to the lawful workings of a mechanistic social reality.

More formal European philosophers, such as Immanuel Kant, sought to reconcile representations of external reality in mind with the motions of matter based on the dictates of pure reason. This impulse was also apparent in the utilitarian ethics of Jeremy Bentham and John Stuart Mill, in the historical materialism of Karl Marx and Friedrich Engels, and in the pragmatism of Charles Smith, William James, and John Dewey. All of these thinkers were painfully aware, however, of the inability of reason to posit a self-consistent basis for bridging the gap between mind and matter, and each was obliged to conclude that the realm of the mental exists only in the subjective reality of the individual.

MIND VERSUS MATTER AND THE DEATH OF GOD THEOLOGIAN

The fatal flaw of pure reason is, of course, the absence of emotion, and purely rational explanations of the division between subjective reality and external reality had limited appeal outside the community of intellectuals. The figure most responsible for infusing our understanding of Cartesian dualism with emotional content was the death of God theologian Friedrich Nietzsche. After declaring that God and "divine will" did not exist, Nietzsche reified the "existence" of consciousness in the domain of subjectivity as the ground for individual "will" and summarily dismissed all previous philosophical attempts to articulate the "will to truth." The problem, claimed Nietzsche, is that earlier versions of the "will to truth" disguise the fact that all alleged truths were arbitrarily created in the subjective reality of the individual and are expressions or manifestations of individual "will."

In Nietzsche's view, the separation between mind and matter is more absolute and total than had previously been imagined. Based on the assumption that there is no real or necessary correspondence between linguistic constructions of reality in human subjectivity and external reality, he declared that we are all locked in "a prison house of language." The prison as he conceived it, however, was also a "space" where the philosopher can examine the "innermost desires of his nature" and articulate a new message of individual existence founded on will.

Those who fail to enact their existence in this space, says Nietzsche, are enticed into sacrificing their individuality on the nonexistent altars of religious beliefs and/or democratic or socialist ideals and become, therefore, members of the anonymous and docile crowd. Nietzsche also invalidated the knowledge claims of science in the examination of human subjectivity. Science, he said, not only exalts natural phenomena and favors reductionistic examinations of phenomena at the expense of mind. It also seeks to reduce mind to a mere material substance, and thereby to displace or subsume the separateness and uniqueness of mind with mechanistic descriptions that disallow any basis for the free exercise of individual will.

Nietzsche's emotionally charged defense of intellectual freedom and his radical empowerment of mind as the maker and transformer of the collective fictions that shape human reality in a soulless mechanistic universe proved terribly influential on twentieth-century thought. As we will discuss in more detail later, Nietzsche sought to reinforce his view of the subjective character of scientific knowledge by appealing to an epistemological crisis over the foundations of logic and arithmetic that arose during the last three decades of the nineteenth century. Through a curious course of events, attempts by Edmund Husserl, a philosopher trained in higher math and physics, to resolve this crisis resulted in a view of the character of human consciousness that closely resembled that of Nietzsche.

The best-known disciple of Husserl was Martin Heidegger, and the work of both figures greatly influenced that of the French atheistic existentialist Jean-Paul Sartre. The work of Husserl, Heidegger, and Sartre became foundational to that of the principal architects of philosophical postmodernism, the deconstructionists Jacques Lacan, Roland Barthes, Michel Foucault, and Jacques Derrida. As we shall see, this direct linkage between the nineteenth-century crisis about the epistemological foundations of mathematical physics and the origins of philosophical postmodernism served to perpetuate the Cartesian two-world dilemma in an even more oppressive form. And it also allows us to better understand the origins of the two-culture conflict and the ways in which that conflict could be resolved.

CARTESIAN DUALISM AND THE TWO-CULTURE WAR

In the United States, French existentialism became the dominant philosophical tradition in institutes of higher learning in the 1960s, particularly in the humanities and social sciences. The writings of the French deconstructionists were embraced with much the same enthusiasm and fervor by students in these disciplines in American colleges and universities from the 1970s to the present. The legacy of this influence is now apparent in the large and growing number of scholars in the humanities and social sciences who embrace philosophical postmodernism. In the tradition of Nietzsche, the more extreme proponents of philosophical postmodernism seek to enact intellectual freedom in open rebellion against the knowledge claims of any discipline or knowledge field. Human consciousness in their view is inextricably connected with and dependent upon linguistic constructions of reality. And they also claim that there are no real or objective truths external to this reality.

In the absence of any basis for positing a real or necessary correspondence between linguistic constructions of reality and external reality, practitioners of philosophical postmodernism embraced Nietzsche's view of human subjectivity as a "prison house of language." Since they also assumed that any construction of reality in the mind of an individual "refers only to itself," these scholars concluded that unambiguous communication between individuals was an illusion at best and a species of mind-less conformity to nonexistent external truths at worst. Like Nietzsche, they argued that the constructs and terms for constructing human reality are the arbitrary inventions of cultural forebears. And they also claimed these constructs and terms became foundational to the collection of narratives that constitutes any given culture because their creators had more power to "discourse" by virtue of their membership in "power elites" and "dominance hierarchies."

Armed with postmodern meta-theories, many scholars in the humanities and social sciences came to view all of human culture as a "text" or collection of narratives. This text, they argued, could be "deconstructed" to reveal the sources of repression and marginalization for women, ethnic minorities, racial groups, and third-world peoples. As the meta-theories entered the mainstream of graduate education in the humanities and social sciences, new modes of postmodernist thought rapidly emerged. The modes were identified with labels such as gender feminism, radical feminism, ecofeminism, gay and lesbian studies, Lacanian psychoanalytic theory, Marxist criticism, Afrocentrism, constructivist social anthropology, deep ecology, and Latourian sociology.

The postmodern posture toward science was also one of subversion. Based on the assumption that science is merely another cultural narrative articulated and perpetuated by those with the power to discourse, scholars in a variety of disciplines attempted to "deconstruct" these knowledge claims and expose their arbitrary origins in the subjective reality of their creators. Many of these scholars advanced the view that the hidden agendas in the "text" called science were products of Eurocentrism, colonialism, capitalism, sexism, and a variety of other "isms" associated with patriarchal Western culture.

The intent here, however, is not to denigrate the practitioners of philosophic postmodernism. It is to demonstrate that the Cartesian division between mind and matter became foundational to much of Western thought since the seventeenth century because it seemed utterly and incontrovertibly consistent with the worldview of classical physics. This division not only served as grounds for divorce between the world of quality, sense perception, thought, and feeling and the world of physical reality. It also laid the groundwork for the divisions between the Enlightenment ideal of the unification of all knowledge and the Romantic ideal of the ultimate integrity and supremacy of individual knowledge; between the conception of God as a creative and generative force in nature and the conception of God as the distant and absentee clockmaker; between constructions of reality based on ordinary language and descriptions of physical reality in the mathematical language of physical theory; and, finally, but no less tragically, between the culture of humanists-social scientists and the culture of scientists-engineers.

Our proposed resolution of the two-world dilemma has substantive scientific validity and will be carefully developed in stages. Since we will draw extensively from knowledge on both sides of the two-culture divide, some of this discussion will at times prove intellectually challenging for members of both cultures. But if our thesis that advances in scientific knowledge have legitimated an alternate view of the relationship between mind and world that could obviate or displace the Cartesian view is correct, this could have large consequences for the future of Western thought.

SCIENCE AS A WAY OF KNOWING

Since much of this discussion deals with the epistemological authority of scientific knowledge, or the bases upon which the knowledge claims of science can be viewed as valid, we should make clear at the onset our position on this issue. Many well-educated humanists and social scientists, including some philosophers of science, have embraced assumptions about the character of scientific truths that serve either to greatly diminish their authority or, in the extreme case, to render these truths virtually irrelevant to the pursuit of knowledge. Those who promote these views typically appeal to the work of philosophers of science, principally that of Stephen Toulmin, Thomas Kuhn, N. R. Hanson, and Paul Feyerabend.

All of these philosophers assume that science is done within the context of a Weltanschauung, or comprehensive worldview, which is a product of culture and constructed primarily in ordinary, or linguistically based, language. One would be foolish to discount this view entirely, as we clearly do not in our brief history of mathematical physics. But it can, if taken to extremes, lead to some rather untenable and even absurd conclusions about the progress of science and its epistemological authority.

The views of the Weltanschauung theorists appear to have also lost currency of late among historians and philosophers of science. The approach that is now most widely endorsed by scholars in these fields is known as historical realism. Historical realism pays "close attention to actual scientific practice, both historical and contemporary, all in the aim of developing a systematic philosophical understanding of the justification of knowledge claims."[1] From the perspective of historical realism, physics is a privileged form of coordinating experience with physical reality that has often obliged us to change our views of self and world.

It is also clear that the cumulative progress of science imposes constraints on what can be viewed as a legitimate scientific concept, problem, or hypothesis, and that these constraints become tighter as science progresses. This is particularly so when the results of theory present us with radically new and seemingly counterintuitive findings like the results of experiments on nonlocality. It is because there is incessant feedback within the content and conduct of science that we are led to such counterintuitive results.

The history of science also indicates that the postulates of rationality, generalizability, and systematizability have been rather consistently vindicated.[2] While we do not dismiss the prospect that theory and observation can be conditioned by extra-scientific cultural factors, this does not finally compromise the objectivity of scientific knowledge. Extra-scientific cultural influences are important aspects of the study of the history and evolution of scientific thought, but the progress of science is not, in our view, ultimately directed or governed by such considerations.

Obviously, there is at this point in time no universally held view of the actual character of physical reality in biology or physics and no universally recognized definition of the epistemology of science. And it would be both foolish and arrogant to claim that we have articulated this view and defined this epistemology. On the other hand, the view of physical reality advanced here is consistent with the totality of knowledge in mathematical physics and biology, and our proposed resolution of epistemological dilemmas is in accord with this knowledge.

In an interdisciplinary work of this kind, the list of those who should be thanked for their contributions is quite long. Suffice it to say here that we are quite grateful to all the men and women who produced the scholarship that made this study possible. If we have not fully disclosed the extent of these contributions, we apologize. The range and complexity of scholarship used here is vast, and space requirements, along with the decision to write a book for the general reader, did not allow for a full explication of this scholarship in all of its complex dimensions.

CHAPTER 1

Quantum Nonlocality: An Amazing New Fact of Nature

Man's perceptions are not bounded by organs of perception. He perceives more than sense (tho' ever so acute) can discover.

Reason or the ratio of all we have already known is not the same as it shall be when we know more.

—*William Blake*

In the strange new world of quantum physics we have consistently uncovered aspects of physical reality at odds with our everyday sense of this reality. But no previous discovery has posed more challenges to our usual understanding of the "way things are" than the amazing new fact of nature known as nonlocality. This new fact of nature was revealed in a series of experiments testing predictions made in a theorem developed by theoretical physicist John Bell in response to a number of questions raised by Albert Einstein and two younger colleagues in 1936.[1] Although Bell's now famous theorem led to the discovery that physical reality is non-local,[2] this was not his primary motive for developing the theorem, and he was quite disappointed by the results of experiments testing the theorem.

Like Einstein before him, Bell was discomforted by the threats that quantum physics posed to a fundamental assumption in classical physics—

there must be a one-to-one correspondence between every element of a physical theory and the physical reality described by that theory. This view of the relationship between physical theory and physical reality assumes that all events in the cosmos are wholly predetermined by physical laws and that the future of any physical system can in theory be predicted with utter precision and certainty. Bell's hope was that the results of the experiments testing his theorem would obviate challenges posed by quantum physics to this understanding of the relationship between physical theory and physical reality.

The results of these experiments would also serve to resolve other large questions. Is quantum physics a self-consistent theory whose predictions would hold in this new class of experiments? Or would the results reveal that quantum theory is incomplete and that its apparent challenges to the classical understanding of the correspondence between physical theory and physical reality were illusory? But the answer to this question in the experiments made possible by Bell's theorem would not merely serve as commentary on the character of the knowledge we call physics. It would also determine which of two fundamentally different assumptions about the character of physical reality is correct. Is physical reality, as classical physics assumes, local, or is physical reality, as quantum theory predicts, non-local? While the question may seem esoteric and the terms innocuous, the issues at stake and the implications involved are, as we shall see, enormous.

Bell was personally convinced that the totality of all of our previous knowledge of physical reality, not to mention the laws of physics, would favor the assumption of locality. The assumption states that a measurement at one point in space cannot influence what occurs at another point in space if the distance between the points is large enough so that no signal can travel between them at light speed in the time allowed for measurement. In the jargon of physics, the two points exist in space-like separated regions, and a measurement in one region cannot influence what occurs in the other. Quantum physics, however, allows for what Einstein disparagingly termed "spooky actions at a distance." When particles originate under certain conditions, quantum theory predicts that a measurement of one particle will correlate with the state of another particle even if the distance between the particles is millions of light-years. And the theory also indicates that even though no signal can travel faster than light, the correlations will occur instantaneously, or in "no time." If this prediction held in experiments testing Bell's theorem, we would be forced to conclude that physical reality is non-local.

After Bell published his theorem in 1964, a series of increasingly refined tests by many physicists of the predictions made in the theorem culminated in experiments by Alain Aspect and his team at the University of Paris-South. When the results of the Aspect experiments were published in 1982, the answers to Bell's questions were quite clear—quantum physics is a self-consistent theory and the character of physical reality as disclosed by quantum physics is non-local. In 1997, these same answers were provided by the results of twin-photon experiments carried out by Nicolus Gisin and his team at the University of Geneva.[3] While the distance between detectors in space-like separated regions in the Aspect experiments was thirteen meters, the distance between detectors in the Gisin experiments was extended to eleven kilometers, or roughly seven miles. Since a distance of seven miles is quite vast in comparison with those involved in quantum mechanical processes, the results of the Gisin experiments were startling. They clearly indicate that similar correlations would exist even if experiments could be performed where the distance between the points was halfway across the known universe.

Although the discovery that physical reality is non-local made the science section of the *New York Times*, it was not front-page news and received no mention in national news broadcasts. On the few occasions where nonlocality has been discussed in public forums, it is generally described as a piece of esoteric knowledge that has meaning and value only in the community of physicists. The obvious question is, Why has a discovery that many regard as the most momentous in the history of science received such scant attention and stirred so little debate? One possible explanation is that some level of scientific literacy is required to understand what nonlocality has revealed about the character of physical reality. Another is that the implications of this discovery have shocked and amazed scientists, and a consensus view of what those implications are has only recently begun to emerge.

The implication that has most troubled physicists is that classical epistemology, which is also known as Einsteinian epistemology, can no longer be viewed as valid. And much of this discussion will seek to demonstrate this is, in fact, the case. This discovery has also revealed, however, the existence of a profound new relationship between parts (quanta) and whole (universe) that carries large implications in terms of our understanding of the character of physical reality in both physics and biology. For reasons that will become clear later, what is most perplexing about nonlocality from a scientific point of view is that it cannot be viewed in principle as an observed phenomenon. The "observed" phenomena in the Aspect and Gisin experiments reveal correlations between properties of quanta, light or photons, emanating from a single source based on measurements made in space-like separated regions. What cannot be measured or observed in this experimental situation, however, is the total reality that exists between the two points whose existence is inferred by the presence of the correlations.

When we consider that all quanta have interacted at some point in the history of the cosmos in the manner that quanta interact at the source of origins in these experiments and that there is no limit on the number of correlations that can exist between these quanta,[4] this leads to another dramatic conclusion—nonlocality is a fundamental property of the entire universe. The daunting realization here is that the reality whose existence is inferred between the two points in the Aspect and Gisin experiments is the reality that underlies and informs all physical events in the universe. Yet all that we can say about this reality is that it manifests as an indivisible or undivided whole whose existence is "inferred" where there is an interaction with an observer, or with instruments of observation.

If we also concede that an indivisible whole contains, by definition, no separate parts and that a phenomenon can be assumed to be "real" only when it is an "observed" phenomenon, we are led to more interesting conclusions. The indivisible whole whose existence is inferred in the results of the Aspect and Gisin experiments cannot in principle be itself the subject of scientific investigation. There is a simple reason why this is the case. Science can claim knowledge of physical reality only when the predictions of a physical theory are validated by experiment. Since the indivisible whole in the Aspect and Gisin experiments cannot be measured or observed, we confront here an "event horizon" of knowledge where science can say nothing about the actual character of this reality. Why this is the case will be discussed in detail later.

If nonlocality is a property of the entire universe, then we must also conclude that an undivided wholeness exists on the most primary and basic level in all aspects of physical reality. What we are actually dealing with in science per se, however, are manifestations of this reality, which are invoked or "actualized" in making acts of observation or measurement. Since the reality that exists between the space-like separated regions is a whole whose existence can only be inferred in experiments, as opposed to proven, the correlations between the particles, or the sum of these parts, do not constitute the "indivisible" whole. Physical theory allows us to understand why the correlations occur. But it cannot in principle disclose or describe the actual character of the indivisible whole.

The scientific implications of this extraordinary relationship between parts (quanta) and indivisible whole (universe) are quite staggering. Our primary concern here, however, is a new view of the relationship between mind and world that carries even larger implications in human terms. As we hope to demonstrate, the stark division between mind and world sanctioned by classical physics is not in accord with our scientific worldview. When nonlocality is factored into our understanding of the relationship between parts and wholes in physics and biology, then mind, or human consciousness, must be viewed as an emergent phenomenon in a seamlessly interconnected whole called the cosmos.

All that is required to embrace the alternate view of the relationship between mind and world that is consistent with our most advanced scientific knowledge is a commitment to metaphysical and epistemological realism and a willingness to follow arguments to their logical conclusions. Metaphysical realism assumes that physical reality is real or has an actual existence independent of human observers or any act of observation. Epistemological realism assumes that progress in science requires strict adherence to scientific methodology, or to the rules and procedures for doing science.

If one can accept these assumptions, most of the conclusions drawn here should appear fairly self-evident in logical and philosophical terms. And it is also not necessary to attribute any extra-scientific properties to the whole to understand and embrace the new relationship between part and whole and the alternate view of human consciousness that is consistent with this relationship. We will, however, take care in this discussion to distinguish between what can be "proven" in scientific terms and what can be reasonably "inferred" in philosophical terms based on the scientific evidence.

MIND-MATTER AND THE GHOST OF DESCARTES

As we saw in the Introduction, the view of the relationship between mind and world sanctioned by classical physics and formalized by Descartes became a central preoccupation in Western intellectual life. And the tragedy of the Western mind is that we have lived since the seventeenth century with the prospect that the inner world of human consciousness and the outer world of physical reality are separated by an abyss or a void that cannot be bridged or reconciled.

In classical physics, external reality consisted of inert and inanimate matter moving in accordance with wholly deterministic natural laws, and collections of discrete atomized parts constituted wholes. Classical physics was also premised, however, on a dualistic conception of reality as consisting of abstract disembodied ideas existing in a domain separate from and superior to sensible objects and movements. The notion that the material world experienced by the senses was inferior to the immaterial world experienced by mind or spirit has been blamed for frustrating the progress of physics up to at least the time of Galileo. But in one very important respect it also made the first scientific revolution possible. Copernicus, Galileo, Kepler, and Newton firmly believed that the immaterial geometrical and mathematical ideas that inform physical reality had a prior existence in the mind of God and that doing physics was a form of communion with these ideas.

In the new mathematical language of classical physics, the more amorphous oppositions and contrasts associated with the symbolic map space of ordinary language became oppositions between points associated with number and mathematical relations. Visualizable aspects of physical reality were translated into the map space of newly invented mathematical and geometrical relationships—the calculus and analytical geometry. And the remarkable result was that the correspondence between points in the new map space of physical theory and the actual behavior of matter in physical reality seemed to confirm a one-to-one correspondence between every element in the physical theory and the physical reality.

The enormous success of classical physics soon convinced more secular Enlightenment thinkers, however, that metaphysics had nothing to do with the conduct of physics, and that any appeal to God in efforts to understand the essences of physical reality in physical theory was ad hoc and unnecessary. The divorce between subjective constructions of reality in ordinary language and constructions of physical reality in mathematical theory was allegedly made final by the positivists in the nineteenth century. This small group of physicists and mathematicians decreed that the full and certain truth about physical reality resides only in the mathematical description, that concepts exist in this description only as quantities, and that any concerns about the nature or source of physical phenomena in ordinary language do not lie within the domain of science.

The result was, as Alexander Koyré wrote, that we came to believe that the real "is, in its essence, geometrical and, consequently, subject to rigorous determination and measurement."[5] Although the reification of the mathematical idea served the progress of science quite well, it has also, said Koyré, done considerable violence to our larger sense of meaning and purpose:

> Yet there is something for which Newton—or better to say not Newton alone, but modern science in general—can still be made responsible: it is the splitting of our world in two. I have been saying that modern science broke down the barriers that separated the heavens from the earth, and that it united and unified the universe. And that is true. But, as I have said too, it did this by substituting the world of quality and sense perception, the world in which we live, and love, and die, another world—the world of quantity, or reified geometry, a world in which, though there is a place for everything, there is no place for man. Thus the world of science—the real world—became estranged and utterly divorced from the world of life, which science has been unable to explain—not even to explain away by calling it "subjective."
>
> True, these worlds are everyday—and even more and more—connected by praxis. Yet they are divided by an abyss.
>
> Two worlds: this means two truths. Or no truth at all.
>
> This is the tragedy of the modern mind which "solved the riddle of the universe," but only to replace it by another riddle: the riddle of itself.[6]

The tragedy of the Western mind, beautifully described by Koyré, is a direct consequence of the stark Cartesian division between mind and world. We discover the "certain principles of physical reality," said Descartes, "not by the prejudices of the senses, but by the light of reason, and which thus possess so great evidence that we cannot doubt of their truth."[7] Since the real, or that which actually exists external to ourselves, was in his view only that which could be represented in the quantitative terms of mathematics, Descartes concluded that all qualitative aspects of reality could be traced to the deceitfulness of the senses.

It was this logical sequence that led Descartes to posit the existence of two categorically different domains of existence for immaterial ideas—the *res extensa* and the *res cognitans*, or the "extended substance" and the "thinking substance." Descartes defined the extended substance as the realm of physical reality within which primary mathematical and geometrical forms reside and the thinking substance as the realm of human subjective reality. Given that Descartes distrusted the information from the senses to the point of doubting the perceived results of repeatable scientific experiments, how did he conclude that our knowledge of the mathematical ideas residing only in mind or in human subjectivity was accurate, much less the absolute truth? He did so by making a leap of faith—God constructed the world, said Descartes, in accordance with the mathematical ideas that our minds are capable of uncovering in their pristine essence. The truths of classical physics as Descartes viewed them were quite literally "revealed" truths, and it was this seventeenth-century metaphysical presupposition that became in the history of science what we term the "hidden ontology of classical epistemology."

While classical epistemology would serve the progress of science very well, it also presented us with a terrible dilemma about the relationship between mind and world. If there is no real or necessary correspondence between nonmathematical ideas in subjective reality and external physical reality, how do we know that the world in which "we live, and love, and die" actually exists? Descartes's resolution of this dilemma took the form of an exercise. He asked us to direct our attention inward and to divest our consciousness of all awareness of external physical reality. If we do so, he concluded, the real existence of human subjective reality could be confirmed.

As it turned out, this resolution was considerably more problematic and oppressive than Descartes could have imagined. "I think, therefore, I am" may be a marginally persuasive way of confirming the real existence of the thinking self. But the understanding of physical reality that obliged Descartes and others to doubt the existence of this self clearly implied that the separation between the subjective world, or the world of life, and the real world of physical reality was "absolute."

As we also saw in the Introduction, much of Western religious and philosophical thought since the seventeenth century has sought to obviate this prospect with an appeal to ontology or to some conception of God or Being. Yet we continue to struggle, as philosophical postmodernism attests, with the terrible prospect first articulated by Nietzsche—we are locked in the prison house of our individual subjective realities in a universe that is as alien to our thoughts as it is to our desires. This universe may seem comprehensible and knowable in scientific terms, and science does seek in some sense, as Koyré puts it, to "find a place for everything." But the ghost of Descartes lingers in the widespread conviction that science does not provide a "place for man" or for all that we know as distinctly human in subjective reality.

THE NEW PHYSICS AND THE MIND-MATTER PROBLEM

In 1905, not long after Nietzsche declared that we are locked in the "prison house of language," an obscure patent office clerk in Geneva, Albert Einstein, published three papers that signaled the beginning of the second scientific revolution. The first paper was on special relativity, the second on Brownian motion, and the third on the photoelectric effect. The mathematical description of physical reality that Einstein and others developed over the next thirty years undermined or displaced virtually every major assumption about physical reality in classical physics. And the vision of reality in what came to be called the new physics immediately challenged the efficacy of the Cartesian division between mind and world.

Most of the creators of the new physics were acutely aware that the potential impacts of this new scientific worldview on our conceptions of the relationship between mind and world were nothing short of revolutionary. And much of what these now famous scientists said about this new relationship was beautifully conceived and written and replete with ideas that carried large human implications. Although there were a few artists and intellectuals without formal training in higher mathematics and physics who vaguely understood these implications, they were largely ignored, until quite recently, by the vast majority of artists and intellectuals.

The reasons why nonphysicists should be intimidated by the prospect of attempting to understand the implications of the description of nature in relativistic quantum field theory are easily appreciated. The mathemat-