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The Metaphysical Foundations of Modern Scientific Imagination

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Since the scientific revolution of the seventeenth century, scientists have sought new knowledge in a relatively straightforward, traditional manner. Experiments would be performed, hypothesis tested, and science would slowly and gradually progress as new data accumulated. Every now and then, of course, a sudden, great leap would occur which unveiled some significant and unexpected new discovery. Today, however, there are some scientific fields in which the frontiers have been pushed so far forward that scientists have found themselves asking questions that have always been considered to be metaphysical, not scientific, in nature. It no longer seems possible in physics to do research without confronting questions once thought to be metaphysical — is it meaningful to speak of time before the creation of the universe? Did the universe have a beginning? What exactly is the logical status of "other universes" if these universes cannot be observed? Is it meaningful to speak of what cannot be observed? For that matter, what meaning should we attach to the existence of extra dimensions of "superstring theory" that are compacted so tiny that they can never be observed?

All these questions relate essentially to the growing rift in modern scientific thought between theory and experiment. For example, the best theoretical physicists today are preoccupied with theories that are extremely difficult to test experimentally, such as the "superstring theory" that has never yielded a direct testable prediction. In their reaction to such an important "metaphysical turn" in current scientific thought, Nobel prize-winning physicist Sheldon Glashow and his Harvard university colleague Paul Ginsparg have likened superstring theory to medieval theology: "Contemplation of superstrings," they write, "may evolve into activity ... to be conducted at schools of divinity by future equivalents of medieval theologians. For the first time since the Dark Ages, we can see how our noble [scientific] search may end, with faith replacing science once again" (Richard Morris, *The Edges of Science,* 1990).

The shift from physics to metaphysics is one of the most common features of the modern scientific imagination. Instead of the scientific revolution's disenchantment of the world, which constituted a reaction to medieval theological teleology of a sacred structure of order inherent in the fabric of the universe, modern science rather tends again to the re-enchantment of the world of nature. Holistic considerations, which can not be tested or proved, begin to dominate the horizon of scientific imagination and determine the edges of science. Acknowledging their growing inability to explain the unimaginable complexity of world phenomena through mere physical principles, scientists are no longer content with the results of experiments and rather seek after an overarching, holistic framework, according to which the phenomenon of the world may be better explained and understood. For example, although physicists cannot observe quarks or gluons, these entities have nonetheless become elements of the model of sub-atomic reality because they lead to predictions that scientists can measure. There is a growing tendency among scientists to tolerate hyperspace and superstring theories, despite the fact that seven of the spatial dimensions of supergravity and six of the dimensions of superstrings (where the one-dimensional strings reside) are hidden and curled up in spaces much smaller than the size of the proton and so are invisible.

The profound difficulties modern scientific thought has encountered lead to the growing understanding that the solution to the mystery of the essential nature of reality ought to be understood in terms of a higher realm of reality — metaphysics — which as yet cannot be an object to our senses or to our most sophisticated scientific instruments. Paradoxically, then, the tremendous advance of science leads rather to a quest after higher, metaphysical considerations that may provide better understanding of the mystery of reality. Such reasoning is evident by the increased crossing of the boundaries from physics to metaphysics in the scientific community. And nowhere is this shift more evident than in the scientific imagination.

To understand the profound transformation apparent in the modern scientific imagination it is necessary to place it in the wider ideological, philosophical and historical context of scientific thought, most specifically in light of the shift from the medieval imagination to the scientific revolution, as well as the change

between the seventeenth century and modern scientific thought. The scientific and philosophical revolution of the seventeenth century led to the destruction of the Cosmos, that is, the disappearance of the medieval conception of the world as a finite, closed, and hierarchically ordered whole (in which the hierarchy of value determined the hierarchy and structure of being, rising from the dark, heavy and imperfect earth to the higher and higher perfection of the stars and heavenly spheres), and its replacement by the indefinite and even infinite universe bound together by the identity of its fundamental components and laws, in which all these components are placed on the same level of being (Alexander Koyr, *From the Closed World to the Infinite Universe,* 1958).

The scientific revolution inaugurated a radical change in the conception of nature and matter. Before the seventeenth century, scientific imagination was based in part on Aristotelian physics, according to which the world had within it principles and powers of development. Natural things changed as a result of their inherent tendency to embody more perfectly the rational form of the essence that defined them. Aristotle's natural world is a world of inherent tendencies, continual transformations, and teleological development; nature is an organic being achieving maturity through self-development. During the thirteenth century, Thomas Aquinas produced a majestic synthesis of Aristotelian natural philosophy and Christian theology that became a prominent form of Christian scientific imagination throughout the medieval period. The essence of Thomas's synthesis was to interpret Aristotle's principles inherent in nature as powers instilled there by God, which He used in his providential work. God *cooperated* with natural powers in a way that respected their integrity while accomplishing his purposes.

The shift from the medieval to the scientific revolution imagination is particularly apparent in regard of the rise of mechanical philosophy during the seventeenth century, the doctrine that all natural phenomena can be explained by matter and its motion, the regularity of which can be expressed in the form of natural laws, ideally formulated in mathematical terms. In medieval scientific imagination nature revealed God's symbolic presence, and was seen as a system of symbols, or signatures of its Creator. During the seventeenth century some leading figures maintained that nature contributes nothing to divine providence because it lacks any integrity and power of its own. Matter is passive and does not possess any inherent qualities or intrinsic powers of its own. It was no longer considered as capable of any power or purpose apart from the hand of God. The seventeenth century scientific imagination thus constructed a new conception of the nature of reality, in contrast to the medieval conception of the "great chain of being" which revealed God's symbolic presence in creation. Nature, as a result, lost integrity and was deprived of any teleological development of its own. The scientific revolution therefore led to the disenchantment of the world.

The mechanical, scientific worldview of the seventeenth century rested on a single, fundamental assumption— *matter is passive.* It possesses no active, internal forces of its own. Matter in the seventeenth century possessed only the passive qualities of size, shape, and impenetrability. Change therefore did not result from the operation of internal principles and powers, as in Aristotelian natural philosophy; instead, the laws of impact and the new principle of inertia explained motion. In short, the seventeenth century science replaced Aristotle's conception of nature as an organic being by the view of nature as a huge machine whose parts undertook various movements in response to other parts doing the same thing. Mechanical philosophy thus became the hallmark of the scientific revolution. In the absence of internal principles and inherent qualities governing change, external laws controlled material bodies. Since matter is totally passive, it is God who imposes natural laws on the world. The mechanization of the natural world was a profound revolution; a new conception emerged of what was real in the world. Particles of matter in motion defined the new reality. The real world was that which could be described in mechanical terms. In such scientific thought, evidently, the concept of nature radically transformed.

An important consequence of the mechanical view of the universe was the discarding of considerations based on value-concepts, such as perfection, harmony, meaning and aim, or the medieval concept of the "great chain of being," and finally the utter devalorization of being, the divorce of the world of value and the world of fact. Instead, the seventeenth century scientific imagination constructed a new concept of the nature of reality, a new vision of nature as homogeneous and nonhierarchical. With the appearance of the mechanical notion of a one-dimensional and homogeneous, the "testimony" of nature became more and more problematic, as did the very notion of divine immanence and activity in the created order. Moreover, since seventeenth century scientific language emptied nature of any intrinsic meanings and qualities of its own, natural phenomena no longer seemed to symbolize and reflect each other and that which is beyond them; the symbolic-allegorical perception of nature as a network of mutual references was discarded. In sum, the medieval sense of God's symbolic presence in his creation, and the sense of a universe replete with transcendent meanings and hints, had to recede if not to give way entirely to the postulates of univocation and homogeneity of the scientific revolution.

The twentieth century scientific imagination seems to be leading back from science to metaphysics by constructing impressive dimensions of reality and new infinite universes, which are hidden from our senses and can be understood only in mathematical, metaphysical terms, as in "superstring," "quantum" and "hyperspace" theories. Thus where in medieval thought God was the source of all beings, and the foundation of all structure of order in the universe, he is now displaced by the power of mathematics which illuminates the possible existence of worlds and universes which lie beyond the material, physical world of everyday life and experience. The profound transformation in scientific imagination from physics to metaphysics did not occur all at once. It is based upon three major and well-defined stages. The first occurred during the scientific revolution, which excluded metaphysical discussions and equivocal qualities, replacing them with a quantified univocal matter. The next stage saw the expansion of abstract mathematical languages in many new areas, such as chemistry, biology, and also the social sciences. Today we are facing a new, or third, phase in the transformation of the

scientific imagination from physics to a mathematical metaphysics, in which scientists tend to rely more and more on mathematical formulations which have no experimental results. The new mathematical vocabulary—including the tenth dimension of *Hyperspace,* which according to Michio Kaku is far beyond our current technological abilities to explore or deduce from an extremely non-sensible logic (*Hyperspace: A Scientific Odyssey Through Parallel Universes, Time Warps, and the Tenth Dimension,* 1994)—cannot be verified by any present experimental results. In this stage, scientists are coming to tolerate hyperspace and superstring theories, as well as models of infinite universes, which have been not actualized by experimental proofs. However abstract and metaphysical some twentieth century mathematical languages may be, they are not based upon private subjective experience and should not be confused with other imaginative vocabularies, such as mystical experiences of higher dimensions or artistic descriptions of reality. Instead, these vocabularies are cultivated within a well-defined mathematical community, which allows metaphysics to flourish as a precise inter-subjective discourse capable of exploring what lies beyond experimental results.

As science advanced and expanded its experimental apparatus, it conquered more and more material domains which had been unknown and traditionally considered as untidy and irrelevant in the scientific imagination of the seventeenth century. With the growing success of the experimental method during the next two centuries, it became more and more apparent that the simplicity and stability of Newtonian atoms no longer fitted the experimental results. A more sophisticated mathematical imagination was needed to capture the complexity and entanglement of differing levels of material organizations, which went on being discovered as time passed. The expansion of mathematics in the next three centuries did not remain in the studies of mathematicians but infiltrated into almost all scientific fields, thus transforming intuitive concepts, such as matter, energy, space, time, and infinity. To the degree that the understanding of nature is demonstrated by the ability to describe and predict the behavior of physical systems, physics and mathematics had made astounding progress by the end of the nineteenth century. By then, highly abstract mathematical fields had been introduced into physics to keep up with the growing elusiveness of matter. Yet the more the experiments with fields became interactive, interrogative, and penetrating, the more elusive matter proved to be. To compensate for the growing complexity of matter, major epistemological transformations occurred in the scientific and mathematical imagination during the twentieth century.

At the beginning of the century, Einstein's mathematical formulations of special and general relativity profoundly modified Newtonian abstractions of space, time, matter, and energy. In addition, the penetrating and interactive gaze of quantum physics completely shook the foundations of classical matter. The deeper and more invading the measurement, the more elusive and spirit-like materiality became. At the subatomic level, quantum matter became an elusive wave-like and particle-like being. In order to move beyond the realm of classical physics, quantum physicists had to give up the paradigm of a detached observer and an independent reality. More far-reaching speculative conclusions regarding the meaning of the quantum void have been expressed in the more popular literature. For example, Fritjof Capra's *The Tao of Physics* (1975) and Gary Zukav's *The Dancing Wu Li Masters* (1979) stressed the close parallels between quantum physics and oriental mysticism.

To capture the increasing elusiveness of subatomic duality, the linkage between the large and the small, and the whole and its parts, physicists can no longer employ the seventeenth century mathematical imagination, which found univocal, homogeneous, stable, controllable, and predictable material billiard balls. The mathematical vocabularies of quantum physics combined with special and general relativity have become a reflection of our own expanding scientific consciousness. Francis Bacon in his "Fourth Aphorism" predicted what was to come when he said that "the universe is not to be narrowed down to the limits of the understanding... but the understanding must be stretched and enlarged to fill in the image of the universe as it is discovered." The gradual evolution in the complexity of the scientific imagination (which continuously urges for simplicity) goes with a gradual shift from anthropocentric affinities to more objective and mathematical perspectives. Or, in A. N. Whitehead's terms, "all science as it grows towards perfection becomes mathematical in its ideas" (*Science and the Modern World,* 1953). This can be seen in the highly abstract contemporary theories of QED (Quantum Electrodynamics), Weinberg Salam theory, and QCD (Quantum Chromodynamics). All these theories are fascinated by with the behavior of spontaneous symmetry breaking. Indeed, during the second half of the twentieth-century, physicists have created a language in which the most fundamental constituents and symmetries of the world cannot be directly observed. Physicists may talk consistently about forces in terms of the preservation of symmetry, but in order to do so they have to be careful in their choice of systems that preserve this symmetry. Physicists cannot observe quarks or gluons, but these entities have, nonetheless, become elements of the sub-atomic reality because they lead to predictions that scientists can measure.

The shift from physics to metaphysics as evident in twentieth century science is based ultimately upon mathematical languages that have paved the way for new metaphysical non-sensual experiences. Indeed, according to theoretical physicist Paul Davies (*God and the New Physics,* 1982), twentieth century mathematical scientific languages have given us much more interesting and precise answers on the nature of creation and reality than any traditional theological discussion has ever produced. Yet, as the physician Lewis Thomas writes: "The greatest of all the accomplishments of twentieth-century science has been the discovery of human ignorance" ("Debating the Unknowable," *Atlantic Monthly,* 1981). This is indeed the essence of the "metaphysical turn" in modern scientific imagination: the growing understanding that the solution to the mystery of the essential nature of reality ought to be understood in terms of a higher realm of reality—metaphysics—which as yet cannot be an object to our senses or to our most sophisticated scientific instruments. Such an important recognition may force us to reconsider once again the notion of divine immanence and activity in the created order: namely, it may reinforce the sense of God's symbolic presence in his cre ation,

and the sense of a universe replete with transcendent meanings and hints. And this may provide in the future rich and imaginative solutions in the scientific imagination about the nature of divine activity and the essential nature of reality, or the relationship between the order of grace and the order of creation.

References

Alexander, H. G. *The Leibniz-Clarke Correspondence* (Manchester: Manchester University Press, 1956).

Barrow, John D. and Joseph Silk. *The Origin of the Universe* (New York: Basic Books, 1994).

Bohm, David. *Wholeness and the Implicate Order* (Routledge and Kegan Paul, 1980).

Boyle, Robert. *An Essay Containing a Requisite Digression, Concerning those that would Exclude Deity from Intermeddling with Matter,* 1663. *Selected Philosophical Papers of Robert Boyle,* edited with an Introduction, M. A. Stewart (Indianapolis: Hackett, 1991).

———. *About the Excellency and Grounds of the Mechanical Hypothesis,* 1674. *Selected Philosophical Papers of Robert Boyle,* edited with an Introduction, M. A. Stewart (Indianapolis: Hackett, 1991).

Brockman, John. *The Third Culture* (New York: Simon and Schuster, 1995).

Brooks, John H. *Science and Religion: Some Historical Perspectives* (Cambridge: Cambridge University Press, 1991).

Burtt, Edwin A. *The Metaphysical Foundations of Modern Physical Science: A Historical and Critical Essay* (London: Routledge and Kegan Paul, 1967 [1924]).

Capra, Fritjof. *The Tao of Physics* (London: BBC Publications, 1977).

———. *The Turning Point* (New York, Simon and Schuster, 1982).

Cohen, Bernard. *The Birth of a New Physics* (New York: Norton, 1985).

———. *Revolution in Science* (Cambridge, Mass.: Harvard University Press, 1985).

Cassirer, Ernst. *The Philosophy of the Enlightenment* (Boston: Beacon Press, 1955 [1951]).

Cole, K. C. *Sympathetic Vibrations: Reflections on Physics as a Way of Life* (New York: Bantam, 1985).

Crease, Robert, and Charles Mann. *The Second Creation: Makers of the Revolution in 20th-Century Physics* (New York: Macmillan, 1986).

Davies, Paul. *God and the new Physics* (New York: Simon and Schuster, 1983).

———. *Superforce* (New York: Simon and Schuster, 1984).

———. *The Forces of Nature* (Cambridge: Cambridge University Press, 1986).

———. *The Mind of God* (London: Penguin, 1994).

Deason, Gary B. "Reformation Theology and the Mechanistic Conception of Nature," in *God and Nature: Historical Essays on the Encounter between Christianity and Science,* eds. Lindberg, David C. and Ronald L. Numbers (Berkeley: University of California Press, 1986).

Dyson, Freeman. *Disturbing the Universe* (New York: Harper & Row, 1979).

———. *Infinite in All Directions* (1988).

Eddington, Arthur. *The Philosophy of Physical Science* (Ann Arbor: University of Michigan Press, 1958).

Feynman, Richard. *QED: The Strange Story of Light and Matter* (Princeton: Princeton University Press, 1985).

———. "The Development of the Space-Time view of Quantum Mechanics," *Science* 153 (1966).

Fine, Arthur. *The Shaky Game: Einstein Realism and the Quantum Theory* (Chicago: University of Chicago Press, 1986).

Freudenthal, Gideon. *Atom and Individual in the Age of Newton: On the Genesis of the Mechanistic World View* (Dordrecht: D. Reidel, 1986).

Funkenstein, Amos. *Theology and the Scientific Imagination from the Middle Ages to the Seventeenth Century* (Princeton: Princeton University Press, 1986).

Gal-Or, Benjamin. *Cosmological Physics and Philosophy* (New York: Springer-Verlag, 1981).

Gell-Mann, Murray. *The Quark and the Jaguar* (New York: W. H. Freeman, 1994).

Gascoigne, John. *Cambridge in the Age of the Enlightenment: Science, Religion and Politics from the Restoration to the French Revolution* (Cambridge: Cambridge University Press, 1989).

———. "From Bentley to the Victorians: The Rise and the Fall of British Newtonian Natural Theology," *Science in Context* 2, No. 2 (Autumn 1988).

Gilson, Etienne. *The Spirit of Medieval Philosophy,* trans. A. H. C. Downes (New York: Scribner, 1936).

———. *The Philosophy of St. Thomas Aquinas,* trans. Edward Bullough (New York: Dorset Press, 1972 [1924]).

Gregory, Bruce. *Inventing Reality: Physics as a Language* (New York: Wiley Science Editions, 1988).

Hawking, Stephen. *A Brief History of Time* (London: Bantam, 1988).

Heidegger, Martin. *What is a Thing?* (Chicago: Henry Regency Co. 1967).

———., "Modern Science, Metaphysics, and Mathematics," in Martin Heidegger, *Basic Writings,* ed. David F. Krell (New York: Harper Collins, 1993), pp. 271-305.

Heisenberg, Werner. *Physics and Beyond: Encounters and Conversations* (New York: Harper and Row, 1971).

Hofstadter, D. R. *Godel, Escher, Bach: An Eternal Golden Braid* (Penguin Books, 1979).

Holton, Gerald. *Introduction to Concepts and Theories in Physical Science* (Princeton: Princeton University Press, 1985).

———. *Thematic Origins of Scientific Thought: Kepler to Einstein* (Cambridge, Mass.: Harvard University Press, 1988).

Issar, Arie S. *From Primeval Chaos to Infinite Intelligence* (Aldershot: Avebury, 1995).

Jacob, Francois. *The Logic of Life: A History of Heredity* (New York: Vintage Books, 1976).

Jacob, Margaret C. *The Cultural Meaning of the Scientific Revolution* (New York: Knopf, 1988).

———. and Teeter, Betty J. *Newton and the Culture of Newtonianism* (Atlantic Highlands, N.J.: Humanities Press, 1995).

Kaku, Michio. *Introduction to Superstrings* (New York: Springer-Verlag, 1988).
———. *Hyperspace* (New York: Oxford University Press, 1994).
Kargon, Robert H. *Atomism in England from Hariot to Newton* (Oxford: Clarendon Press, 1966).
Kauffman, Stuart A. *Origins of Order: Self-Organization and Selection in Evolution* (New York: Oxford University Press, 1993).
Kline, Morris. *Mathematics and the Search for Knowledge* (New York: Oxford University Press, 1985).
Koyr, Alexander. *From the Closed World to the Infinite Universe.*
Lange, Frederick A. *The History of Materialism and Criticism of Its Present Importance* (New York: Harcourt, Brace, 1925).
Lindberg, David C. and Ronald L. Numbers, eds. *God and Nature: Historical Essays on the Encounter between Christianity and Science* (Berkeley: University of California Press, 1986), p. 186.
Mayr, Otto. *Authority, Liberty & Automatic Machine in early Modern Europe* (Baltimore: Johns Hopkins University Press, 1986).
Morris, Richard. *The Edges of Science* (New York: Prentice Hall, 1990).
Newton, Sir Isaac. *Sir Isaac Newton's Mathematical Principles of Natural Philosophy and His System of the World,* ed. Florian Cajori, 2 vols. (Berkeley: University of California Press, 1962).
Pagels, Heinz. *The Cosmic Code: Quantum Physics as the Language of Nature* (New York: Simon and Schuster, 1982).
———. *Perfect Symmetry: The Search for the Beginning of Time* (New York: Simon and Schuster, 1985)
Penrose, Roger. *The Emperor's New Mind* (Oxford: Oxford University Press, 1989).
Prigogine, Ilya and Stengers, Isabelle. *Order out of Chaos* (Bantam, 1984).
Sarasohn, Lisa T. *Gassendi's Ethics: Freedom in a Mechanistic Universe* (Ithaca: Cornell University Press, 1996).
Smolin, Lee. *The Life of the Cosmos: A New View of Cosmology, Particle Physics, and the Meaning of Quantum Physics* (New York: Crown, 1995).
Stephen, Sir Leslie. *History of English Thought in the Eighteenth Century,* 2 vols. (New York: Harbinger, 1962 [1876]).
Westfall, Richard S. *The Construction of Modern Science: Mechanisms and Mechanics* (Cambridge: Cambridge University Press, 1977 [1971]).
———. *Force in Newton Physics: The Science of Dynamics in the Seventeenth Century* (London: Macdonald, 1971).
Wheeler, J. A. *Genesis and Observership* (Princeton University: John Henry Laboratories, 1976).
Whitehead, A. N. *Science and the Modern World* (Cambridge: Cambridge University Press, 1953).
Weinberg, Steven. *The First Three Minutes: A Modern View of the Origin of the Universe* (New York: Basic Books, 1977).
———. *Dreams of a Final Theory* (London: Vintage, 1995).
Zohar, Dana. *The Quantum Self* (London: Harper Collins, 1991).
Zukav, Gary. *The Dancing Wu Li Masters* (Rider, 1979).

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