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Overcoming the limitations of the classical paradigm: post-Newtonian implications for a social science

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Iowa State University, 1994

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Overcoming the limitations of the classical paradigm:

Post-Newtonian implications for a social science

by

Martin E. Hansen

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INTRODUCTION

It is a defining characteristic of modern Western culture that Science[1] holds the most esteemed position in regard to forms of knowledge and “ways of knowing.” How this came about is a focal point in the history and philosophy of science and can be traced back to the early Greeks circa 600 B.C. Of all the various ways of knowing, science also provided the model adopted by the social sciences during the Enlightenment. In spite of numerous postmodern critics and an ongoing hermeneutical self-reflection and critique, “normal science” continues to form both the academic and applied foundation for the social sciences. Such a contention, of course, shall not go undefended. However, of greater interest in the development of Science and its influence on the social sciences is the emerging shift in scientific paradigms from a mechanical-reductionist and deterministic Newtonian understanding of the ontological world to a non-deterministic and more holistic view of the world in general (Capra, 1991; Herbert, 1985). This shift can be seen in the increasing popularization of quantum theory, its derivatives (e.g., catastrophe theory, chaos theory, self-generating systems, complexity), and their ever-broadening range of application. Most interesting in these developments is that, while the natural sciences are seeking to integrate sociological variables (e.g., observation, human action, consciousness, interpretation) into their methods and analyses, the social sciences

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[1] Herein "Science" (with an upper case "S") will refer to the epistemological dimension of Science as a "way of knowing." The term will begin with a lower case letter when in reference to specific scientific areas, divisions, methods, applications, etc. of the larger epistemological dimension.

have, for the most part, disregarded any implications the post-Newtonian scientific revolution might have for their own development.

The purpose herein is neither a critique of normal science nor of positivism. Given the assumption that the social sciences, and sociology in particular, are founded on the ontological premises of the Classical Newtonian scientific paradigm,[2] the question arises as to what the social sciences, and sociology in particular, might look like if rebuilt from a post-Newtonian foundation. Might some of the existing ontological, epistemological, and practical problems in the social sciences (e.g., order vs. disorder, the mind-body problem, macro-micro gap, object-subject fragmentation, cause-effect indetermination) be overcome given a new scientific paradigm? What implications does the post-Newtonian paradigm have for overcoming the limits of understanding existing now in the social sciences?

In pursuing the answers to these questions it is first necessary to outline the meaning and development of what Kuhn (1970) and others have come to call "normal science." Implicit in that outline are epistemological questions concerning alternative ways of knowing and the rise of Science to its lofty ideological position in modern Western culture, including its place within sociology and the social sciences. Similarly, the meaning and development of post-Newtonian science must be explored along with its potential implications for a new social "Science." A new model of the

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[2] The influence of Newtonian physics on the social sciences is not accidental – August Comte patterned "social physics" (later to be called "sociology") after Newton's original distinctions between "statics" and "dynamics."

social sciences can then be constructed which takes into account the new premises of the emerging post-Newtonian paradigm. The application and utility of such a model for the social sciences can then be tested and evaluated.

REVIEW OF THE HISTORY AND PHILOSOPHY OF WESTERN SCIENCE PART I: THE CLASSICAL PARADIGM

Paradigms, Normal Science, and Ways of Knowing

Paradigms and the predominance of normal science

Normal science is defined by Kuhn (1970, p. 10) as "research, firmly based on one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice." According to Kuhn (1970), in any scientific field of endeavor, normal science is contingent upon the emergence of a predominant paradigm in that field. Such paradigms can be thought of as "models from which spring coherent traditions of scientific research" in regard to the specification of "law, theory, application, and instrumentation" (Kuhn, 1970, p. 10). Paradigms evolve from theories, yet are considered to be more general and more encompassing than any single theory within a specific scientific field (Kuhn, 1970, pp. 17-18, 182). What saves Kuhn from a tautological argument is the assertion that new paradigms emerge not from the accumulation of the everyday scientific activities of which he speaks, but from scientific "revolutions" in which a new theory "requires the reconstruction of prior theory and the re-evaluation of prior fact, an intrinsically revolutionary process that is seldom completed by a single man and never overnight" (Kuhn, 1970, p. 7).

Such an observation is essential in understanding the development of science at the community (or within-disciplines) level of analysis. However, it is here that a sense of ambiguity enters the notion of scientific paradigms. As Kuhn's postscript in the second edition (1970, p. 177) of his book points out, scientific communities exist on several different levels of analysis. Much of Kuhn's work admittedly speaks to theories and paradigms within specific academic and/or applied disciplines and sub-disciplines "consisting, perhaps, of fewer than twenty-five people" (1970, p. 181). The question arises as to the sociological utility of a concept which addresses itself to such relatively limited units of analysis—particularly given the high regard and esteem Science enjoys in modern Western culture. Kuhn (1970, pp. 17, 179) makes a distinction between pre-paradigm and post-paradigm "schools." Yet the schools of which he speaks were actively engaged in the delineation of laws, theories, applications (methods), and instrumentation, i.e., Kuhn's original definition of a paradigm. Sociologically, perhaps, it could be postulated that Kuhn's pre-paradigm and post-paradigm examples are really part of a larger epistemological unit of analysis called Science, while his community-level paradigms exist in reference to what he previously defined as "normal science." The question still remains: Can the notion of scientific paradigms be extended to more general levels and units of analysis?

The word science comes directly from the Latin *scientia*, being derived from the Latin verb *scire*, meaning "to know" (American Heritage Dictionary: Microsoft

Bookshelf 1992 Edition, 1992). Thus, given the original meaning of the term, might Science be viewed as a particular paradigm within the larger context of ways of knowing? Where does Science fit within a larger epistemological context?

Ways of knowing and normal science

No consensus exists among philosophers, much less among social scientists, in regard to the process and scope of knowledge and its acquisition. Nonetheless, a broad review of the epistemological literature identifies several[3] ways of knowing. One manner of acquiring and assimilating knowledge that is commonly described in the literature is aesthetic/ecological. Dewey (1920/1968, p. 115) defined knowledge as "beholding and noting" and comparatively discussed "the right way to know" in terms of aesthetical considerations.

> In fact, the whole conception of knowledge as beholding and noting is fundamentally an idea connected with esthetic enjoyment and appreciation where the environment is beautiful and life is serene, and with esthetic repulsion and depreciation where life is troubled, nature morose and hard. (Dewey, 1920/1968, pp. 115-116)

Aesthetics refers to the "study or theory of beauty and of the psychological responses to it; specific., the branch of philosophy dealing with art, its creative sources, its forms, and its effects" (Webster's New World Dictionary, 1988, pp. 21-22). The aesthetic way of knowing refers to knowledge based on distinctions about and qualitative references to beauty, shape, and form. Aesthetics, according to the

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[3] These are listed alphabetically in the text. The sequential order of presentation is not meant to indicate a hierarchy of importance or position.

American Heritage Dictionary: Microsoft Bookshelf 1992 Edition, (1992), refers to the "perception" of the "innate qualities" of an object or thing.[4] Quality could thus be considered an aesthetic type of knowledge. Society itself can be described as an aesthetic form (e.g., Marcuse, 1969, p. 49; Featherstone, 1992). According to Dewey (1920/1968), and Milbrath (1989), ecological awareness also derives from the aesthetic way of knowing—the result is a motivation to alter (or *not* to alter) the shape and form of nature to meet alternative aesthetic or otherwise pragmatic ends. Though notions about what is "beautiful" and "not beautiful," like descriptions of most qualitative characteristics, are for the most part socially constructed and thus vary between cultures—an aesthetic way of knowing appears to be common to most, if not all, cultures. This aesthetic/ecological way of knowing is indelibly intertwined with our socially constructed system(s) of values (Milbrath, 1989, pp. 5-6)—we tend to value that which is beautiful, moral, ethical, and desirable while devaluing that which is considered ugly and undesirable in shape or form. This idea of values has very important implications for science. These implications will be examined later.

Another way of knowing found in epistemological literature, and sociological writings in particular, is affective-emotive. This way of knowing associates

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[4] Herein the aesthetic way of knowing could also include perceptions and the appreciation of culturally defined "innate" qualities such as moral, good, pleasing, etc. The broader sense of the term includes those perceptions and appreciations which elude references to both sensory experience (sight, hearing, touching, smell, taste) and emotional conditions (fear, anger, love, elation, etc.).

phenomena with feeling states, emotions, and cognitive gratification.[5] Weber (1921/1978, pp. 24-25) distinguished the affective way of knowing from other (e.g., rational) forms in his analysis of the various influences on social action. According to Weber,

> Purely affectual behavior also stands on the borderline of what can be considered "meaningfully" oriented, and often it, too, goes over the line. It may, for instance, consist in an uncontrolled reaction to some exceptional stimulus. It is a case of sublimation when affectually determined action occurs in the form of conscious release of emotional tension. (1921/1978, p. 25).

Examples of affective-emotive knowledge would include love, fear, anger, etc. Though emotion and affectivity are frequent objects of analysis in the social sciences, affective-emotion as a way of knowing is, for the most part, rejected in "scientific" disciplines in favor of more "rational" modes of inquiry (see Weber, 1903-1917/1949). From an epistemic and ontological perspective, this exclusion results in somewhat of a schizophrenia in normal science (especially the social sciences). Not to mention certain scientists.

Another way of knowing addressed by Weber (1921/1978) and also discussed in mainstream philosophical texts (e.g., Hospers, 1967) is authoritative knowing. This refers to knowledge acquired and assimilated from respected external sources. Authoritative knowledge, by definition, assumes the source to be reliable and the content to be valid. Though authoritative knowledge is not a primary form of

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[5] Emotional gratification, as is often distinguished from sensual and physical gratification. It is recognized herein that any sharp distinction between physical and cognitive phenomena may have limited utility.

knowledge, as a result of the massification of culture through electronic and print media, it is becoming an increasingly significant way of knowing as compared to alternative primary forms (see Marcuse, 1964, p. 4). Much of our knowledge—especially formal education—is rooted in authoritative knowledge. Science is typically comfortable with authoritative knowledge—as long as science is the authority involved. Of course, the definitive way of knowing in the sciences is empirical-kinesthetic.

Empirical-kinesthetic knowledge is knowledge obtained through and associated with the immediate sensory experiences of sight, smell, hearing, touch, and taste. Of all ways of knowing, "sense experience is the most obvious" (Hospers, 1967, p. 122). Empiricism, as a way to knowledge,

> is based on the belief that only that which can be experienced by the senses is real, and that the final test of scientific truth is the experience of the senses . . . In this sense empiricism is basic to most scientific thought. (Theodorson & Theodorson, 1969, pp. 130-131)

Kinesthetic refers to information processing and memory functions stored in the muscles of the body. The term has two Greek roots: *kinein*, meaning "to move," and *aisthesis*, meaning "perception" (Webster's New World Dictionary, 1988, p. 744). Our senses not only process information, but provide a means of storage and retrieval by means of kinesthesia. An example of the kinesthetic dimension of knowledge is found at the end of your wrist. Try writing with the opposite hand that you are accustomed to writing with. You will find that although you "know" how to form the letters and words, your alternative hand does not possess the same ability (knowledge?) to form them as your accustomed one (unless, of course, you're ambidextrous). It is a curious trait of modern Western science that empiricism, as a way of knowing, is considered superior to all other forms of knowledge. If the goal of Science is an ontological and/or epistemological understanding of the world,[6] empiricism immediately excludes a major part of the "reality" one is trying to observe, describe, and understand. Nonetheless, the empirical-kinesthetic way of knowing forms the very foundation upon which modern Western scientific thought is built. Far removed from empiricism as a way of knowing, we find faith.

Faith is "a firm belief in something for which there is no evidence" (Hospers, 1967, p. 141). It typically involves a belief or nonrational trust in some external person, will, or force. The belief in God is an example of knowing through faith.[7] While faith cannot be a true *source* of knowledge (see Hospers, 1967, pp. 140-141), a significant part of our everyday ways of knowing nonetheless involve the invocation of faith. A more meaningful example might be the fact that certain positivists invoke faith in Science and materialism in much the same way that practicing Christians invoke faith in Christ or God (see Outwaithe, 1987, pp. 29-31, for an enlightening

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[6] The pragmatic school of scientists (e.g., Weinberg, 1992) minimize any ontological or epistemological agenda for science. This crass realist approach contends that the fundamental goal of science is to discover the underlying laws of nature and that science need not and should not be concerned with philosophical issues such as knowing and being.

[7] Admittedly, religious faith will significantly overlap with authoritative ways to knowledge; the critical distinction might be made that faith could be thought of as primary knowledge while authority is derived from secondary sources.

critique). The extent we are motivated by faith and trust, however, is usually taken for granted until that trust or faith is broken. For example, the postmodern critique of science provides a hermeneutical challenge to the faith in normal science as it has been historically practiced in addition to a "loss of faith in the self as a social object" and the loss of faith in the "possibilities for enlightened social action" (Katovich & Reese, 1993, pp. 391-392). In the same manner as emotive-affective and most other ways of knowing, the social sciences recognize faith as an object of study and knowledge but reject it as a valid means or way of knowing. The schizophrenia of normal science is thus exacerbated.

Max Weber (1921/1978) proposed that tradition also exerts a significant influence on social action. An important way of knowing and coming to knowledge could thus be called historical-traditional. Our success as a species is due not so much to our complex reasoning abilities, but to our ability to transmit acquired knowledge across geography and time and to then act based on that accumulated knowledge within our own histories and biographies. Accordingly, intelligence itself is comprised largely of the ability to recognize and associate patterns from past experiences (one's own and the experiences of others). One must conclude that the influence of history is paramount at both the individual and cultural levels of analysis. According to Weber , "The great bulk of all everyday action to which people have become habitually accustomed approaches this [traditional] type" (1921/1978, p. 25). Kuhn points out that normal science is based on the cumulative findings of past scientific research (1970, p. 10). While many of the natural sciences are, by necessity, historical (e.g., geology, archaeology, paleontology), history is seldom seen as a significant way of knowing in and of itself. In the social sciences, history as a way of knowing is most often transformed into one of two types of historicism: (a) Popper's (1957) critical term for the search for historical evidence of laws of social development, or (b) hermeneutics and the deconstruction of historical textual materials (see Abercrombie, Hill, & Turner, 1988, p. 114; also Ross, 1991, pp. 4-7). In all cases, tradition as a form of knowledge and basis for action is cast aside and subsequently transformed into logical-empirical types of analyses. History as a means to knowledge is typically seen as incompatible with empiricism, that way of knowing which remains the foundation for all inquiry in modern Western science. Thus, the vast influence tradition, habit, and history play on our lives remains an occasional object of scientific study, yet is seldom if ever recognized as a valid epistemic way of knowing within the context of modern Western science.

According to Kuhn (1970), one way of knowing with the potential to give birth to new scientific paradigms is intuition-revelation. This takes the form of "novelty" within normal science, occasionally to the degree that it results in a paradigmatic crisis which demands either resolution or revolution. The most obvious example in recent history is Einstein's "thought experiments" leading to his special theory of relativity. To arrive at the special theory of relativity, Einstein imagined himself riding on a beam of light. In doing so, he had the revelation that time and space are mathematical functions of each other, dependent upon the relative velocity and coordinates of an observer with the speed of light as a mathematical constant. Even so, intuition and revelation lack recognition, description, and support by the community of normal science practitioners—in light of the fact that the formulation of scientific theories and hypotheses rely (in varying degree) on intuition, hunches, and guesses about the "real" causes and outcomes of events. Here, intuition and revelation do not even have the status of objects of inquiry—they are denied any existence whatsoever. If novelty is recognized at all, it is typically within the context of empirical observation and/or logical induction and deduction. In fact, the logical-rational way to knowledge is the one significant remaining way of knowing to be discussed.

The word "logic" comes from the Greek *logos* meaning "word, reckoning, or thought" (Webster's New World Dictionary, 1988, p. 795). It is closely related to, and sometimes synonymous with, what Weber (1921/1978) identified[8] as rationality, i.e., the calculation of means and ends. As a way of knowing, logical-rational might best be defined as "sequential reasoning." It stands in opposition to other forms of rationality and ways of knowing, e.g., affective-emotive, historical-traditional, authoritative (see Weber, 1921/1978, pp. 22-26). In normal science, logic is used to

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[8] Weber's reference (1921/1978, p. 24) refers specifically to *zweckrational* social action, or that action which is oriented by calculating in advance both the means and the ends of the situation. Various translations of the original work label this type of rationality "formal rationality," "instrumental rationality," or "means-ends rationality" (see Kalberg, 1980, for an excellent discussion of Weber's treatment and usage of the term).

impose abstract categories and conceptual order on empirical sense data. The logical method comes from Aristotle.

> Classical, or Aristotelian, logic is concerned with the formal properties of an argument, not its factual accuracy. Aristotle, in his Organon, held that any logical argument could be reduced to a sequence of 3 propositions (2 premises and a conclusion), known as a SYLLOGISM, and posited 3 laws as basic to all logical thought: the law of identity (A is A); the law of contradiction (A cannot be both A and not A); and the law of the excluded middle (A must be either A or not A). Aristotle assumed a correspondence linking the structures of reality, the mind, and language, a position known in the Middle Ages as REALISM. The opposing school of thought, NOMINALISM, represented by WILLIAM OF OCCAM, maintains that language and logic correspond to the structure of the mind only, not to that of reality. (Concise Columbia Encyclopedia: Microsoft Bookshelf Edition, 1992)

Regardless of whether one takes a realist[9] position or an alternative one in regard to the place of an independent objective reality, rational logic (in the Aristotelian sense of the categorization of and search for "real" natural forms) remains the method and process by which normal science finds (or alternatively, imposes) order in the natural world. Sometimes this takes the form of theorizing and hypothesizing, sometimes deduction or induction. It is a primary way of knowing in the everyday operation of normal science.

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[9] It is acknowledged that realism has different meanings, depending on the school of thought applied. Aristotle's "realism" referred to the "reality" of pure forms, concepts, and qualities beyond individual objects and our direct observation of them – this usage is in opposition to "nominalism," which argues that, although material objects are real in the sense that they exist independently of the observer, the *qualities* of an object exist primarily in the mind. Alternatively, in the philosophical literature, "realism" refers to the idea that there is an objective "reality" that exists completely independent of human observation – this usage is in opposition to "idealism," which suggests that any independent objective reality is a necessary fiction created by our minds (Concise Columbia Encyclopedia: Microsoft Bookshelf Edition, 1992). Finally, a sociological usage of realism exists in reference to "uncovering the (real) underlying and often unobservable mechanisms that connect phenomena causally, not merely in showing that the phenomena are instances of some observed regularity" – this stands in opposition to crass positivism which rejects anything unobservable as "unreal" (Abercrombie, Hill, & Turner, 1988, p. 203).

Table 1. An epistemological model of alternative ways of knowing

Ways of Knowing	Description or Example
Aesthetic-Ecological	Innate qualities of beauty, shape, form
Affective-Emotive	Emotions; e.g., love, anger, fear
Authoritative	Accepted external source; e.g., media
Empirical-Kinesthetic	Sense data; see, hear, touch, smell, taste
Faith	Trust or belief in external will, force, etc.
Historical-Traditional	Habits and unquestioned conventions
Intuition-Revelation	Hunches or guesses in absence of reason
Logical-Rational	Sequential reasoning; e.g., theory, deduction. induction, hypothesizing

An epistemological and ontological model which can provide a context for the operation of Western normal science is summarized above. These "ways of knowing" are not intended to be mutually exclusive nor logically exhaustive. Many overlap, additional ways of knowing could be argued for, any of those identified above could be argued against. There is, of course, a multitude of articles, books, and arguments with alternative—even contradictory—epistemological and ontological models. The goal of this discussion is not to resolve any age-old questions about knowing and being; instead, an attempt has been made to place science within a larger epistemological and ontological context.

The eme[illegible] [illegible]sis [illegible]

To the end of [illegible] [illegible]eing, one can make a rather [illegible] ontological limits of [illegible] [illegible]ence relies almost exclusively [illegible] Empirical in the exclus[illegible] [illegible]ense of Aristotelian categori[illegible] [illegible]nizing. Other ways of knowing, [illegible] faith, historical tradition [illegible] scientific study. However [illegible] accepted as valid *mea*[illegible]

As will be discuss[illegible] [illegible]st, exists and operates inde[illegible] science, the observer and [illegible] [illegible]ce, methods, measuring inst[illegible] epistemology and onto[illegible] observer “objectively” be[illegible] epistemological and onto[illegible] [illegible] me apparent. As [illegible]

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[10] Most any introductory social [illegible] science (e.g., [illegible], 1993; [illegible] for

The emerging crisis in normal science

To the end of placing normal science in a larger context of knowing and being, one can make a rather mundane conclusion about the epistemological and ontological limits of Western normal science: As a way of knowing, normal science relies almost exclusively on empirical and logical ways and means of knowledge.[10] Empirical, in the exclusive reliance on immediate sense data, and logical, in the sense of Aristotelian categorization, deduction and induction, theorizing, and hypothesizing. Other ways of knowing, e.g., aesthetic-ecological, affective-emotive, authoritative, faith, historical-traditional, and intuition-revelation are sometimes *objects* of scientific study. However, seldom, if ever, are these alternative ways of knowing accepted as valid *means* to knowledge and understanding.

As will be discussed later, in Newtonian normal science, ontological reality exists and operates independent of the observer. In Post-Newtonian quantum science, the observer chooses the "reality" observed through her or his own presence, methods, measuring instruments, and attributive perceptions. This problem of epistemology and ontology has always existed in the social sciences: How can the observer "objectively" be both subject and object of investigation? Here the epistemological and ontological limits of Classical Newtonian normal science become apparent. A schizophrenia is thus manifested first in Science, as a way and means of

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[10] Most any introductory social science text identifies these two ways of knowing as the foundation for science (e.g., Macionis, 1993; McConnell, 1986; Robertson, 1987).

understanding and appreciating ontological reality and, consequently, in science as a way and means of accomplishing that goal. How did this schizophrenia develop? What are the origins and historical precedents of what might be called Classical or Newtonian "normal science?" Can normal science in general—herein meaning "the assumptions and methods of science inherited from Galileo and Newton which rely explicitly on logical and empirical ways of knowing", i.e., the Classical Paradigm—reject or ignore most of our other primary ways of knowing and still provide an adequate ontological and epistemological understanding of reality?

The Historical Origins of the Classical Paradigm

Ancient Greek roots

By most accounts, the roots of Western science are found in Ionia, a part of Ancient Greece, around 600 B.C. According to Burke (1985), the ancient Ionians were descendants of hardy Greek mainlanders who took to the sea about 1000 B.C. Thales of Miletus, 625-545 B.C., is credited with the invention of natural philosophy, which was later to be called science (Mason, 1962, p. 25). It was a unique combination of sociocultural and environmental factors that precipitated the rise of science in Ionia at that time.

> Both [Egyptian and Babylonian] cultures developed mythical explanations for Creation which, they felt, had happened not long before each of them had come into existence. With gods responsible for all aspects of the world and with minimal science and technology developed for practical necessities, their simple cosmology was complete. The environment made no demands on them which they were not able to meet.... The uneven nature of [the Ionian]

> physical environment, with marginal agricultural productivity, little room for landward expansion, hostile neighbors, and the need to trade, made the colonial Greeks dynamic in outlook. (Burke, 1985, pp. 14-15)

> It may have been because of their economic circumstances that the Ionians took a radically new view of the world . . . . These Ionians began, ahead of all others, to ask fundamental questions about how the universe worked. Where the older [Egyptian and Babylonian] had been content to refer to custom, edict, revelation and priestly authority, Thales and the others looked to naturalistic explanations for the origin of the world and everything in it. They began to find ways of exploring nature, in order to explain and control it, the better to ensure their survival. (Burke, 1985, p. 15)

The social and ecological conditions within which the Ionians[11] had to meet their subsistence resulted in their need to find alternative ways of understanding nature other than traditional authority and faith in the gods. While the understanding of nature in Ancient Babylon and Egypt was the privilege of priestly scribes and forbidden to craftspeople, the Ionians viewed the workings and understanding of nature from a more pragmatic perspective.

> The analogies used by the Miletian philosophers to explain the structure and workings of the world differ markedly from those employed in the creation stories of the Egyptians and the Babylonians. The Greeks regarded neither organic procreation nor the magic word of command as world-building principles, relying more upon analogies based upon craft processes. (Mason, 1962, p. 27)

According to Burke,

> The Ionian interest in practical answers to questions about the world led to the first, crude attempts to find mechanisms, rather than gods, responsible for natural phenomena. (1985, p. 16)

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[11] Also known as Milesians, since Milesia was the capital of Ionia at that time.

This prompted the Ionians to develop an almost exclusive interest in physics or (what we now refer to as) cosmology (Sahakian, 1968).

> Cosmology is that branch of metaphysics which deals with the nature or essence of the orderly universe—the cosmos. The Ionian philosophers set for themselves the task of ascertaining the nature of substance, of cosmic matter, of the very *stuff* out of which the entire universe is composed. (Sahakian, 1968, p. 1)

Epistemologically, during the time of the Ionians, logical rational thought surpassed authority, tradition, and faith as a primary way of knowing. However, it is interesting to note that the rise of Ionian science and the very existence of competing ways of knowing resulted from the existence of persistent unanswered questions—this is congruent with Kuhn's premises about how paradigms and worldviews tend to shift. The Ionians, for the most part, felt the five senses were fairly reliable indicators of events in the natural world. At least in terms of written records, the Ionians were the first to combine logical and empirical ways of knowing as primary means to knowledge. The result was the birth of Science as an epistemological and ontological way of understanding the universe and our place in it—even though this new ontological perspective still lacked some of its more modern methodological characteristics, i.e., experimentation, deduction, induction, hypothesis testing. Nonetheless, many of our modern assumptions about Science and the reality it seeks to understand can be traced back to the Ionians.

Thales, though none of his original writings have been found (see Donner, Eble, & Helbling, 1967, pp. 60-61), is considered to be the first to propose that nature is made up of a fundamental substance, in his case, water. His conclusions were formed, in part, on empirical observations.

> [Thales] and his students examined beaches, clay deposits, phosphorescence and magnetism. They studied evaporation and condensation, as well as the behavior of the winds and the changes in temperature throughout the year, from which they deduced the dates of the seasons. (Burke, 1985, p. 16)

Thales is credited with predicting the first solar eclipse. He also traveled to Egypt where he studied Egyptian geometry[12] and subsequently introduced those ideas to the West. Thales offered the first geometric proof that a circle is bisected by its diameter. As the first recorded natural philosopher, Thales thus introduced logic, empirical observation, and mathematical geometry to what would later be called Science.

Anaximander, 611-547 B.C., Thales' pupil, deduced that all life originated in the sea and that higher life forms evolved from lower forms. He also proposed a theory of the transfiguration of matter which was similar to the laws of thermodynamics in Newtonian systems: Matter is never completely destroyed but continually changes from one form into another.[13] Like his teacher, Thales, Anaximander felt the five senses were reliable indicators of the "real." The ontological and epistemological conflicts now associated with crass empiricism were resolved by assuming that all matter originated in God, which (whom?) was imperceptible and thus unquestionable. Anaximander, like Thales and the other

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[12] The great pyramids are but one example of the scope and depth of the knowledge of geometry flourishing in Ancient Egypt.

[13] In actuality, given the hylozoistic assumptions of the early Ionians, this transfiguration of matter could be considered to be more like the Hindu belief in reincarnation than the first law of thermodynamics.

Ionian natural philosophers, was a *hylozoist*, meaning he believed that all "life is a property or derivation of matter, that life and matter are inseparable, or that matter possesses a spiritual component" (American Heritage Dictionary: Microsoft Bookshelf Edition, 1992). This led to the idea that natural processes operated "according to laws of trespass and retribution.... And into that from which things take their rise, they pass away once more, as is meet, for they make reparation and satisfaction to one another according to the order of time" (Anaximander in Mason, 1962, p. 27). Mason describes this anthropomorphic tendency:

> Thus in winter, cold commits an injustice to heat, and in summer, heat exacts its retribution. All things are transient, for when an object comes into being, it commits an injustice against things already existing and a reparation must be made. The notion that there was a principle of retribution in natural processes was derived by analogy from the customs of human society in which the practice of vengeance preceded that of the due process of law. Thus the early meaning for the Greek word for *cause*, 'aitia', was *guilt*. Such a notion was replaced ultimately by the conception that nature, like human society, was governed by laws. (1962, pp. 27-28)

Thus, the very idea of natural laws comes indirectly from the Ionian anthropomorphic perspective called hylozoism—and was intended as an analogy to human societies. In the absence of experimentation, it seems such observations relied more on intuition than they did logic or empiricism. Nonetheless, it is remarkable how close the intuition of the Ionians comes to our modern "objective" empirical models.

Heraclitus of Ephesus, 544-484 B.C., did not see absolute natural laws as the inevitable outcome of hylozoistic retribution. Instead, Heraclitus proposed that retribution resulted in an ongoing process of change and flux in nature, i.e., *becoming*

(Sahakian, 1968, p. 7). Structure, to Heraclitus, was the inevitable yet transitive result of the process of change (Mason, 1962, p. 28). "You could not step in the same river twice, for other and yet other waters are ever flowing on" is the most famous remnant of Heraclitus' natural philosophy (Heraclitus, in Donner, Eble, & Helbling, 1967, p. 65). Heraclitus proposed that natural change, however, proceeds in accordance with an innate rationality:

> To Heraclitus, therefore, we must grant the distinction of having been the first to discover natural law, the laws of science. This natural principle, reason (or the law of nature), which he termed *Logos*, is the rational principle which dominates immutable law. The *Logos* of the world makes possible the orderly behavior of cosmic processes of action and reaction. These processes combine to make things grow and then to disintegrate in a ceaseless cycle from life to death, from composition to decomposition, from creation to destruction, from chaos to cosmos and vice versa, all in a sequence of rhythmical change. Everything in the universe undergoes this procedure of change and counter-change in a cyclical order, and only the *law* of change abides—that is, the *Logos*. (Sahakian, 1968, p. 8)

With the assumption that all is in a process of *Becoming*, as opposed to existing in a structural condition of *Being*, Heraclitus argued that the empirical way of knowing did not offer much insight into understanding the ongoing process of change. "Eyes and ears are bad witnesses for men, since their souls lack understanding" (Heraclitus, in Donner, Elbe, & Helbling, 1967, p. 65). The ideas of Heraclitus were not well received by the Ancient Greeks and stand in an uncomfortable contrast with today's general framework(s) of modern Western science.

> [It was] Heraclitus' belief that everything was in a state of flux, that change was the basic certainty of the universe. A belief of this sort, contradicting one of man's most deeply felt convictions, inevitably produced philosophic controversy. For ordinary men as well as philosophers, the search for

> something permanent seems to be a necessary part of being. The eternal nature of God and the spiritual world is probably the most widely held answer to this search in Western thought. (Donner, Elbe, & Helbling, 1967, p. 61)

Donner, Elbe, & Helbling (*ibid.*) offer a profound insight into the development of Western thought: Our success as a species relies on our ability to control and predict the outcome of natural events. This requires the assumption of some *a priori* structure and permanence. Though change is inevitable, it is not always welcomed. As will be discussed later, the Classical paradigm sees change primarily as the motion of the hands on the clockwork of the universe—with the clock itself, operating according to innate natural laws, as an *a priori* concept. Heraclitus did not assume structure *a priori*; instead he proposed that structure is tentative and derives from dynamic processes (when this conclusion re-emerged 2500 years later in quantum mechanics, it was received with—and still elicits—comparable trepidation).

Within the philosophical literature, the ideas of Parmenides, circa 515 B.C., and Zeno, circa 490-430 B.C, are usually cast in direct opposition to those of Heraclitus.

> Parmenides, who became the second great leader of the Eleatic school, developed a view in direct antithesis to Heraclitanism. Whereas Heraclitus interpreted all reality as change, Parmenides pictured the universe as a single, permanent substance (the theory of Metaphysical Monism). (Sahakian, 1968, p. 9)

> Among the pre-Socratics, both Parmenides (*fl.* 475? B.C.) and Zeno, his disciple (*b.* 490? B.C.), opposed Heraclitus' changing world with the assertion that nothing changes. Parmenides based his belief on the argument that since our thoughts and our words are about real substances which have to exist, which still exist, and which will go on existing, all things must be unchanging. Zeno, slightly younger than Parmenides, opposed the idea of change by

> creating his famous paradoxes in which motion itself—the flight of an arrow, for instance—is regarded as being simply a succession of static moments. Further, since an arrow aimed at a target must pass through a series of infinitely divisible distances, it will never reach its target. (Donner, Elbe, & Helbling, 1967, p. 61)

Parmenides still did not resort to empiricism to refute the assertions of Heraclitus. Parmenides, like Heraclitus, found sense data unreliable, like the illusion one enjoys while watching a series of rapidly moving yet carefully coordinated picture frames (i.e., watching a movie). Zeno also challenged the empirical way of knowing with the same revelation that Einstein had 2400 years later: Motion is relative to the observer and it always expresses a relationship between two objects in time and space. The ideas of the Eleatic philosophers (Parmenides, Zeno, etc.) only thickened the metaphysical soup. An alternative way of resolving the conflict between Being and Becoming (and the still unhappy marriage of empirical and logical ways of knowing) was offered by the Pythagorean philosophers.

Pythagoras, 580-497 B.C., combined faith, logic, aestheticism, and intuition in his model of ontological reality. At the foundation of Pythagorean philosophy is the supremacy of ideas above immediate sense perceptions (Sahakian, 1968, p. 20). According to the Pythagoreans, there exists an innate order in the world which is grounded in "pure" mathematical and geometric forms.

> For the Pythagoreans numbers provided a conceptual model of the universe, quantities and shapes determining the forms of all natural objects. At first they thought of numbers as geometrical, physical, and arithmetical entities made up of unit points or particles. They arranged such units at the corners of various geometrical figures and spoke of them as triangular numbers, square numbers, and so on. Thus, for the Pythagoreans, numbers had a geometrical

> shape as well as a quantitative size, and it was in this sense that they understood numbers to be the forms and images of natural objects. (Mason, 1962, p. 29)

It is a legacy of the Pythagoreans that gives nature the quantitative character which predominates today's modern Western normal science. Dualism and reductionism were also part of the Pythagorean system. To the Pythagoreans, stemming from their focus on the aesthetic way of knowing, nature was comprised of opposites. "The opposing objects co-operate to produce a harmony; and just as in music harmony emerges from opposites, so the opposing forces in the universe are reconciled by a harmony of numbers" (Sahakian, 1968, p. 22). Yet another alternative to reconciling Parmenides' Being with Heraclitus' Becoming was proposed by the Ancient Greek Atomists at Abdera.

The founder of the Atomist school was Leucippus of Abdera, circa 440 B.C. Leucippus supported Parmenides' contention that Being characterizes ultimate reality. This Being, according to the Atomists, consisted of fundamental particles which they called *atoms* ("a" meaning *not*, and "tom" meaning *divisible*, thus translated "not divisible"). Democritus, circa 420 B.C., student of Leucippus and the father of Materialism, proposed that the "natural order of the world" and the "characteristics of nature" were innate in these atoms. "Mechanistic causes (atomic force or weight) account for all phenomena . . . . Atoms alone exist, possessing motion and filling empty space" (Sahakian, 1968, pp. 17-18). From the Atomists (and later, from a deal Descartes cut with the church), Western science inherited the dualism of mind and matter.

> [The Atomists] assumed that the Being is manifest in certain invariable substances, the mixture and separation of which gives rise to the changes in the world. This led to the concept of the atom, the smallest indivisible unit of matter . . . . The Greek atomists drew a clear line between spirit and matter, picturing matter as being made of several 'basic building blocks'. These were purely passive and intrinsically dead particles moving in the void. The cause of their motion was not explained, but was often associated with external forces that were assumed to be of spiritual origin and fundamentally different from matter. In subsequent centuries, this image became an essential element of Western thought, of the dualism between mind and matter, between body and soul. (Capra, 1991, p. 21)

According to Democritus, hedonism results from the false information given by senses: "The true joys are those of the spirit, attained through knowledge of truth, not through sense experience" (in Sahakian, 1968, p. 19). Democritus began the search for a "deep reality" beyond the reach of our immediate senses but still perceptible with the aid of reason and logic. The schizophrenia of modern Western science begins with this dualism of thought.

> The dualistic thought which runs throughout the philosophy of Democritus, beginning with the distinction between two basic types of knowledge (between sense experience [*empirical*] and rational intellect [*logical*]) culminates in two interpretations of ethics (Hedonism and Eudaemonism) and two views of reality: as phenomenal reality and as metaphysical (or ontological) reality. Phenomenal reality refers to our knowledge of appearances, while metaphysical reality refers to our knowledge of real objects, the true essences of objects. The term *phenomenal reality*, apparently first used by Democritus, became part of the permanent vocabulary of philosophers. In modern philosophy it has come to mean our relative knowledge of sense objects—the world which the senses depicts for us—in contrast to general reality. By metaphysical reality Democritus meant the absolute, not relative, knowledge of Being or of the essences of objects . . . . [It] was Democritus who set the stage in metaphysics for the eventual development of two diametrically

> opposing points of view: Platonic Idealism, and Metaphysical Materialism coupled with Relativism. (Sahakian, 1968, pp. 19-20)

The Atomists, upon closer examination, did not resolve the dilemma between Being and Becoming. Instead, they pursued a reductionist argument which resulted in a dualistic understanding of ontological reality. It was an ontology separated from its own epistemological foundations—a "reality" of the senses which differed *a priori* from the "reality" of the mind. The path of the idealists (e.g., Plato) would combine logical with intuitive ways of knowing under the assumption that the senses provided an unreliable foundation for perceiving the world. The metaphysical materialists (e.g., Democritus) would combine logical and empirical ways of knowing under the assumption that "reality" was an objective material phenomenon that could (at least in its practical or *secondary* forms) be perceived by the senses and understood (in terms of fundamental, non-reducible, or *primary* forms, i.e., atoms) using reason (see Sahakian, 1968, pp. 18-20).

With the fall of Ionia to Persia in 530 B.C., Athens came to be the center of intellectual activity in the Ancient World. The Sophists in Athens shifted their philosophical concerns from cosmology and ontology to epistemology and problems of man.[14]

> The leading Sophist philosopher, Protagoras [481-411 B.C.] applied the [Heraclitean] idea of change to epistemology—the study of knowledge and

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[14] The use of the term "man" is not to indicate a preference of gender. Though the term "human" would be more politically correct, in this context the term "man" should be taken in its generic gender-free sense. The intent is to reflect the tone, feel, and form of the original writings, free from the modern political ideological contexts of today.

> how it is obtained. He concluded that knowledge and truth are both dependent on judgments by the individual. (Sahakian, 1968, p. 25)

The questions shifted from laws of nature to laws of civil society; from a focus on the nature of man to the focus on how man should live.

Socrates, 470-399, B.C. accorded logical and empirical scientific knowledge an important place in the hierarchy of knowledge, but gave supremacy to insight as a primary form of knowing. Socrates detested emotions and the affective way of knowing, arguing that such mental conditions blocked the paths to truth and virtue. According to Socrates, logic and debate provide a test for truth—yet insight provides the ultimate ways and means of all knowing.

> Socrates considered himself to be a sort of midwife, drawing truth from its repository in each man's soul, where truth is dormant and simply needs to be awakened. He concluded that all truths have been inherited from the individual at birth, that is, from an existence prior to his earthly existence . . . Truth is laid bare through the *Socratic dialectic*, a method of conversation by which all possible points of view regarding a problem, issue, or subject are set forth and debated from every angle. (Sahakian, 1968, p. 33)

Plato of Athens, 427-347 B.C., revived the paradox of Being and Becoming, but from an ethical concern more so than an ontological one. The self, in Plato's ideal conceptualization, had a phenomenological component in addition to an ideal (read *real*) component.

> According to Plato the transient sensory life of the individual, consisting of his thoughts, perceptions, and experiences which comprise his phenomenal or tangible world, ceases at death, and he then returns to existence in the ideal world, the real universe, from which he came and to which he must conform. (Sahakian, 1968, p. 55)

For Plato there existed two worlds: one of the mind, the other of material things. Apparently, the hylozoistic principles of the early Ionians had been discarded by Plato's time. Now the question was not whether nature sought retribution in the same manner as humans, but whether social laws could operate in the same manner as do (now taken *a priori*) natural laws. Plato's writings have significant implications for social philosophy in particular—the interest in a pure "natural" philosophy was not revived until later by Plato's pupil, Aristotle of Stagira in Thrace, 384-322 B.C. Aristotle has been referred to as *"the philosopher"* whose influence has "permeated the work of scientists and philosophers throughout the ages" (Sahakian, 1968, p. 62).

The first enduring scientific paradigm began with Aristotle (Einstein & Infeld, 1938; Kuhn, 1970). At the foundation of Aristotle's work lay logic. The method of scientific inquiry devised by Aristotle relied on the use of logic to derive inferences about the objective world. This inferential process could take either of two forms, either deductive or inductive. The deductive form, or *syllogism*, made inferences about particular cases based on the properties and appearance of the whole. The other type, *induction*, examines the parts or individual cases and makes logical inferences about the properties of the whole or *universal* (Sahakian, 1968, p. 63).

> Aristotle understood truth to mean the agreement of knowledge with reality; truth exists when the mind's mental representations (ideas) correspond with things in the objective world. On the other hand, error (falsehood) occurs when our judgment (the combination of ideas in the mind) does not occur with the genuine relationships among things in the outer world . . . . Genuine proof results when valid inferences are drawn from true or ultimate premises (self-evident propositions), or from premises which are based on true or self-

> evident propositions—ultimate statements or axioms that must be taken for granted because they cannot or need not be proved. (Sahakian, 1968, p. 63)
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> Logical reasoning makes us certain that our conclusions are true, and thus provides us with accepted scientific proofs of universally valid propositions or statements. *Scientific inference* thus consists of conclusions based on true and certain principles or premises. (Sahakian, 1968, p. 63)

Aristotle's logic was based on intuition as a primary source of knowing. He distinguished between the "essence" of an object (the real ontological being in the Platonic sense) and its "accidental" characteristics which do not form part of the defining characteristics of the object (Sahakian, 1968, p. 65). This does not, however, imply that Aristotle was an idealist. Aristotle was uncomfortable with the dualism of Platonic thought and shifted away from Plato's idealism toward a more naturalistic understanding of the world.

> For Plato, the sense world realized itself by imitating the ideal world, whereas for Aristotle, the Platonic ideals realize themselves through the phenomenal world. For Aristotle, Plato's universals (Ideals) were always to be found in particulars (empirical objects). Plato's ontologically real object—Ideal—was given the term *essence* by Aristotle; at other times he called it *form*, *intelligible essence*, or *notional essence*. Whereas for Plato, the essence (ideal object) is actually independent of particular things, for Aristotle essence is real only when it is actualized, that is, only as it realizes itself in phenomenal objects and therein takes on some appearance detectable by sense experience. (Sahakian, 1968, p. 67)

While Plato explained reality in terms of ideal forms, Aristotle proposed a reality of ultimate objects and categories. The Aristotelian logical method was also a method of classification. He formulated ten "categories" of concepts (or defining attributes) by which to categorize empirical objects: "substance, quantity, quality, relation, location, time, position, possession, active, and passive" (in Sahakian, 1968, p. 64).

> [An] object is adequately defined when its specific characteristics shared by all members of its species are combined with the qualities shared by all members of its genus or general class. . . . [Furthermore, a] general or universal concept is classifiable with more general concepts, and these with still more general concepts until at last one arrives at final or ultimate concepts. (Sahakian, 1968, p. 64)

Similar to, and connected with, Aristotle's description of ultimate concepts was his description of ultimate and final causes.

To Aristotle, unlike Plato and most of the metaphysicians before him, god was not the active director of the universe.

> Platonic theology had its mythical apparatus of the divine artist, fashioning the order of Nature, after the pattern of a perfect model, which includes the Forms of animal species. But Aristotle has renounced this expedient: he denies the separate existence of ideal Forms, and with the disappearance of the model, the creator too must disappear. (Cornford, 1968, pp. 97-98)

Aristotle's god was a perfect and fully realized god, and thus did not need to fiddle with the clockwork of the universe. Aristotle's god is the first and final cause of everything in the universe—everything has a place and purpose in the grand design.

According to Aristotle, matter itself is an initial cause (*material cause*), and the form that matter takes constitutes the essence of that material (*formal cause*). Motion, according to Aristotle, is the *efficient cause*, and finally, the ultimate purpose or "realization" of the material form is the *final cause* (in Sahakian, 1968, p. 68). Aristotle replaced an active god with a systemic teleology of matter and form. This removal of divine intervention from the everyday experiences of man laid a new foundation and orientation for science. Assuming the world was shaped by a predetermined rational design, humans could realize their “final cause” through the rational pursuit of “self-contemplative existence”[15] (Sahakian, 1968, p. 70). This was the beginning of science as an “autonomous activity”—“they [the Greeks] wanted to know—for the sake of knowing” (Sullivan, 1933, p. 9).

Though Aristotle relied increasingly on empirical observation as a methodological tool (Mason, 1962, p. 41), he never did fully reconcile the empirical and logical ways of knowing into a formal scientific methodology, instead, preferring to rely on simple observations, intuition, and formal logic (Einstein & Infeld, 1933; Sahakian, 1968).

> The [Aristotelian] method of reasoning dictated by intuition was wrong and led to false ideas of motion which were held for centuries. Aristotle’s great authority throughout Europe was perhaps the chief reason for the long belief in this intuitive idea. . . . The discovery and use of scientific reasoning by Galileo was one of the most important achievements in the history of human thought, and marks the real beginning of physics. This discovery taught us that intuitive conclusions based on immediate observation are not always to be trusted, for they sometimes lead to the wrong clews. (Einstein & Infeld, 1933, pp. 6-7)

Aristotle and his students left a substantial record of empirical observations, the most impressive being a complex classification of over 540 animals, many of which were carefully dissected and anatomically illustrated. The first record of experimentation,

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[15] St. Thomas Aquinas, 1125-1274, later revived these ideas of Aristotle and popularized *scholasticism*. Scholasticism combines religious faith as a way of knowing with logical-rational ways for the purpose of realizing and understanding god and divine purposes and will. Today most Western scientists see faith as antithetical to the logical empirical methodology of normal science.

however, came from one of Aristotle's successors at the Lyceum from 287 to 269 B.C., Strato of Lampsacus.

> Strato appears to have gone beyond observation to experiment. He weighed a piece of wood before and after heating, and he found that the charcoal produced had the same volume as the wood but possessed a smaller weight. Strato presumed therefore that matter had departed from the wood, leaving small vacuous pores. In another experiment he showed that partially evacuated vessels would pick up water, an effect which he ascribed to the water filling the voids between the particles of air. Strato was of the view that bodies in general consisted of minute particles with voids between them. If there were no such voids, he argued, light would not be able to pass through water and air, nor would heat be able to flow from body to body. (Mason, 1962, pp. 46-47)

By most accounts (e.g., Mason, 1962; Sullivan, 1933), intellectual activity was in decline in Athens by the time of Strato. The Athenians were defeated by the Spartans in 404 B.C., and again by Philip of Macedonia in 338 B.C. The result was a general shift in their world views from scientific curiosity to either superstitious Stoicism or Epicurean detachment (Mason, 1962, p. 48; McKay, Hill, & Buckler, 1983a, pp. 130-131). After the vast military conquests of Aristotle's pupil (and son of Philip of Macedonia), Alexander the Great, the intellectual center of the Western world moved from Athens to the new city of Alexandria in Egypt.

Alexander's armies took with them engineers, geographers, and surveyors. According to Mason, this provided "the means, and perhaps the stimulus, for the change in Greek science from the speculative to the empirical which occurred in the lifetime of Aristotle" (1962, p. 48). Alexander's reign lasted but a decade, and another of Aristotle's pupils, Ptolemy, gained power in Egypt. Due in part to

Ptolemy's building of the great library at Alexandria, combined with his efforts to collect not only the great writings but the great minds of the era in one place, science was kept alive at Alexandria for almost two centuries. The Athenians stigmatized the practical arts, but science in the Alexandrian period found new applications in medicine, engineering, architecture, geography, and surveying. Many of the scientists of this era were also engineers and/or physicians (e.g., Archimedes of Syracuse, 287-212 B.C.; Herophilus of Chalcedon, circa 300 B.C.). It was during the post-Athenian Hellenistic period that the military came to drive scientific and technological pursuits.

> Archimedes developed a number of machines to thwart the Roman army. . . . In the Hellenistic period the practical applications of the principles of mechanics were primarily military, for the building of artillery and siege engines. Archimedes built such machines out of necessity, but they were of little real interest to him. (McKay, Hill, & Buckler, 1983a, p. 134)

Archimedes is credited with several inventions still in use today including the Archimedian screw for raising and lowering water, and the compound pulley. His interests may have been practical, but his methods were decidedly scientific.

> In his works Archimedes presented scientific knowledge as a deductive system of theorems from self-evident propositions, like the geometry of Euclid. It is possible however that he first obtained his results experimentally, and then deduced them from the postulated axioms, for he tells us in his work *On Method* that he made thought experiments in the investigation of areas and volumes. He measured the areas of plane figures by weighing, in imagination, their shapes cut out of uniform material, thus gaining some insight into their relationships, which he then proceeded to demonstrate mathematically. (Mason, 1962, p. 51)

Archimedes befriended Eratosthenes of Cyrene, 285-204 B.C., who is credited with the first accurate measurement of the circumference of the earth. Another

Alexandrian astronomer, Aristarchus of Samos, 310-230 B.C., measured the distances between the earth, moon, and sun, and was the first to propose a heliocentric model of the solar system.[16] Erasistratus of Chios, 300-260 B.C., a student of Stratos, pursued crude yet scientific experiments, mostly in the area of physiology and respiration. Alexandrian contributions to the growth of Western scientific thought may have been practical, but that is not to deny them a place of importance.

Late Alexandrian and Hellenistic contributions to natural philosophy were few and seldom original (Mason, 1962). By 200 B.C., the Romans had spread across the Mediterranean and extended their arm into Africa, the Far East, and Western Europe. Under external pressures, Alexandria went the way of its intellectual predecessors Ionia and Athens. "The school of Alexandria declined in the second century B.C." (Mason, 1962, p. 57). With its decline, and the subsequent rise of Rome's political power, came the decline and decay of science as a means of understanding the world.

Rome and the decline of Western science

By most accounts, Rome contributed little if anything to the advancement of modern Western science.

> The Romans did not add a great deal to science. Their contribution lay elsewhere, in the field of organization—the formation of a public medical service, the building of roads and aqueducts, the introduction of the Julian

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[16] The influence of Aristotle and his theory that the heavens and earth were separate realms which obeyed different laws resulted in the open rejection of the heliocentric model. This rejection would last for over a millennium.

> calendar, and the formulation of Roman law to regulate their organizations. (Mason, 1962, p. 61)
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> The early Romans had little respect for literature, art, and science; these were not the proper concerns of a Roman gentleman. When they did become popular, it was largely through the influence of Greek house slaves, following the conquest of south Italy. Therefore it was the Greek forms which became fashionable; old Roman work was almost wholly lost. (Garraty & Gay, 1972, p. 200)

Sullivan also denies the existence of any scientific contributions made by the Romans.

> In the meantime the [Greek] spirit of disinterested curiosity, and man's delight in this new and wonderful mathematical faculty, withered and died under the cold blight of the Roman Empire. The Romans were essentially practical people, and they adopted the 'What is the use of it?' attitude towards all abstract speculation. Such science as they had was borrowed from the Greeks, and they seem to have valued it solely for its practical applications in medicine, agriculture, architecture, and engineering. As a natural consequence of their obsession with practical affairs the Romans created nothing in science. (Sullivan, 1933, p. 10)

Thus, apparently, the Roman emphasis on practical affairs did not result in an ongoing focus on the empirical way of knowing in regard to science.

The strength of the Greek intellect was the awareness and reliance on a variety of competing ways of knowing, including faith, logic, aesthetics, revelation, etc.—the Romans lacked this flexible worldview. The Romans eventually came to appreciate Greek art and literature but had little appreciation for the intellectual culture that produced it—especially Greek natural philosophy and the "curious delight" the Greeks found in pursuit of nature's secrets (Sullivan, 1933, p. 10; Mason, 1962, p. 62). Roman science was a practical political science of governmental, military, and economic means and ends. As such, it built the largest empire the

Western world had yet known. The many administrative problems of ruling the largest empire in the world need not be outlined here. The greatest of these problems was maintaining a credible ideology in the face of a multitude of cultural influences and political problems. This was accomplished by elevating the importance of faith as a way of knowing. Other-worldly Christian faith—not a faith in this-worldly science— would provide the framework within which the Roman government could assert its credibility and mobilize its subjects (McKay, Hill, & Buckler, 1983a, pp. 187-188).

The medieval period

Thus, logic and this-worldly empiricism faded as predominant ways of knowing and were replaced by faith and the authority of the church. It was St. Augustine, 354-430 B.C., who finally consolidated the various Christian sects into a unified church and ideology. St. Augustine's goal was to take the philosophy of the earlier Greeks and "remove all elements except for faith" as the primary way of knowing (St. Thomas Aquinas in Donner, Eble, & Helbling, 1967, p. 265).

> With one mighty stroke of his pen, the great saint [Augustine] had banned an almost complete catalogue of the ancient sciences. . . . he told [his contemporaries] to raise up their eyes to heaven and, most explicitly, forget about the things of this earth. (Goldstein, 1980, p. 57)

St. Augustine and the medieval fathers of the Roman Catholic Church rewrote history to reflect Platonic idealism coupled with an omnipotent other-worldly god.

According to Goldstein, only an other-worldly ideology such as that of St. Augustine's medieval Christianity could rebuild the ruins of the Roman Empire.

> The end of Roman civilization in the West . . . would have left a mood of collective despair, an orgy of bleak and impenetrable hopelessness, had it not been for the inspiration of Christianity. (Goldstein, 1980, p. 55)
>
> Christian teachings offered a hope for the victims of the catastrophe [of the fall of the Roman Empire]. The hope—the only hope the gigantic disaster could conceivably leave in its wake—rested in the conviction of the essential unreality of the things of this world, in contrast to the abiding reality of an invisible world that, by its very nature, had to remain immune from the shocks of secular experience. If the original Christian faith had contained certain world-denying elements, a handful of religious philosophers, the Latin fathers of the church, reinterpreted basic Christian teachings to suit the new mood of the Western world in order to alleviate the despair that afflicted [the] community. Where original Christianity held out the hope of an afterlife by stressing the chance of salvation for every Christian follower of Christ who would mold his life to prepare himself for heaven, the new "Western" Christianity asked for the complete denial of the world of the senses, asserting that life in this world is neither of primary significance nor, in a philosophical sense, actually "real". . . . it was probably the only ideology by which the West could hope to survive. It proved its vigor and vitality by ruling the Western mind for almost a thousand years. (Goldstein, 1980, pp. 55-56)

If religious faith and authority answers all questions about the nature and origins of humans and the universe, science is not a necessary social construction within that particular culture.

> Science seems to grow most luxuriantly in cultures with a positive attitude toward the world of the senses; it appears to wither in cultures with an emphatically spiritual, otherworldly bent. (Goldstein, 1980, p. 43)

Most sources agree that from the advent and fall of the Roman Empire to the Renaissance nothing of significance was produced in Western science (Sullivan, 1933, p. 11).

> The ensuing centuries in Europe, up to the time of the Renaissance, also produced nothing in science. But this was not because the medievalists were exclusively absorbed by practical affairs. On the contrary, some of the greatest abstract thinkers the world has ever produced appeared at this time. But they had an outlook on life that made science unnecessary. Science could tell them nothing that they wanted to know, and they had no curiosity about the sort of things science could tell them. The medievalist lived in an orderly universe. He knew the principles on which it was constructed, and he knew the meaning and purpose of everything in it. He knew the scheme of creation; he knew the end that every created thing was made to serve. He derived this information from two sources, reason and revelation. The highest discoveries of the human reason were embodied in the works of Aristotle; the Scriptures contained divine revelations on matters not accessible to reason. By synthesizing these two kinds of information everything worth knowing could be learned. . . . The medievalist lived in a purposeful universe of which he himself was the centre. The reason why phenomena existed was to be found in their bearing on the eternal destiny of man. Nothing had any meaning except in so far as it fitted into this great logical scheme. In this atmosphere it is obvious that science would appear to be a trivial activity. It could be of no real importance, for the reason that it was concerned with merely secondary questions. How things happened was of no importance compared with the question of why they happened. Even Roger Bacon, the one man of his time who insisted in the experimental investigation of nature, agreed that the importance of this investigation was that it would assist in elucidating theology. It was only when faith in the all-pervading purposefulness of natural phenomena had faded that the scientific method of inquiry became important. (Sullivan, 1933, p. 11)

At the end of the Dark Ages[17] faith and reasoned logic were combined to form scholasticism, the primary philosophy of the times. Scholasticism explained all purpose and origin of the origin in divine terms, however, humans, through reason, could come to realize and understand this divine plan. Interestingly, two ideas were coming together that would later provide the cracks for science to seep back into the

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[17] The Dark Ages are usually defined as the time in the Western world from the fall of Rome to about 1000 B.C. when the Roman Catholic Church started to promote intellectual activities and founded one of the first universities in Bologna circa 1088 B.C..

Western worldview: logic as a valid way of knowing and nature as a rational and predictable force.

The influence of Islam and the East

Meanwhile, the science of the Greeks was absorbed by the growing influence of Islam throughout the Middle East and Africa. This influence expanded as far west as Spain, where Cordova became one of the few intellectual centers of Western Europe at the time (Mason, 1962, pp. 100-101; McKay, Hill, & Buckler, 1983a, pp. 248-249). In the eighth century, Islamic men of science were asked to come to both Damascus and Baghdad, where they studied the works of Aristotle and other Greek natural philosophers. Islam, from its conception, has had an unusual combination of both this-worldly and other-worldly concerns. The Muslim faith differs from the Christian faith of the Dark Ages in one important way: The Islamic religion encourages this-worldly scientific and political pursuits, while the focus of medieval Christianity was strictly other-worldly, in spite of the explicit utilization of scholastic "reason" in both cases. It was the this-worldly focus of Islam which kept Western science alive during the medieval period.

The great influence of Islam on Western science and culture should not, however, overshadow the importance of Eastern science and culture to the West (see Mason, 1962, pp. 73-102). The Chinese, for example, developed complex irrigational technologies, papermaking, and metallurgy as early as 1500 B.C. Chinese medicine and astronomy were considerably more advanced than those of the Ancient Greeks of the same era. India also was known for its metallurgy, as well as complex mathematics and the discovery of zero as a number. Even so, most of these innovations came to the West indirectly through Islam due to the fact that the broad scope of Islam's influence attracted important scientific ideas and practices from India and the Far East. According to McKay, Hill, and Buckler, "Arabic knowledge of science and mathematics, derived from the Chinese, Greeks, and Hindus, was highly sophisticated" (1983a, p. 249). Islam not only kept science alive for its later rediscovery in the West, but "Arabic mathematics, medicine, philosophy, and science played a decisive role in the formation of European culture" (McKay, Hill, & Buckler, 1983a, p. 249).

The growing schism between reason, faith, and authority

It was by accident that the eleventh century European religious scholars opened the door which would lead the West out of the Dark Ages and on the Renaissance path to Enlightenment. The existing ideology of the church, inherited from St. Augustine, made it clear that all ontological questions had already been answered through god and expressed by Platonic other-worldly idealism. Throughout the west, from the early conception of the Roman Catholic Church, religious scholars were wholly dependent upon the initial translations of Greek philosophy by the first fathers of the church. These translations consisted mostly of selectively edited nonsecular Platonic idealism purged of all secular references. Furthermore, medieval religious scholars were required to work exclusively in their native Latin. Thus, they could not have read or understood ancient Greek even if such sources were available. The growing influence of scholasticism and the increasing support of education by the church led to a renewed interest in the original Greek texts (mainly to seek additional historical support for existing church doctrines). However, the language barrier had yet to be overcome. Many Western philosophers and scholars could read Arabic. This is where Islam found the opportunity to share the rich and vast knowledge it had acquired while alternative ways of knowing lay dormant in the West.

> Western philosophers still could not read Greek, but Arabic philosophers, who could, had begun translating Aristotle into their own language as early as the ninth century. Arabic and Christian culture had a meeting ground in Spain, where a Moslem culture had flourished alongside a Christian one since the eighth century. Toward the middle of the twelfth century Christian scholars in Spain began translating the works of Arabic philosophers into Latin, and by the end of the century almost the entire body of Aristotelian thought was available in that language. Until that time, Christian scholars had been pretty much confined in their knowledge of Greek thought to the adaptations of Platonic philosophy incorporated into the writings of the Fathers of the Church. (Donner, Eble, & Helbling, 1967, p. 314)

What the Christian scholars found was not a historical foundation for existing “truths,” but a serious challenge to the very authority that encouraged the logical pursuit of divine truth to start with. The knowledge possessed by the Greeks was comprehensive, enlightening, and empirically sound. Nature proved to be orderly and predictable, but not necessarily as a result of other-worldly predestination. The other-worldly ontology which permeated the ideology of the church for nearly a millennium was now challenged by the practical this-worldly science of Aristotle and his pupils.

> It is the origin and the basis of the Platonic and Augustinian Catholic doctrine to the effect that the sensed world is not the real world, and that the sensed self is not the real self but merely the symbol or sign of more real or immortal self beyond. In fact, it was the Platonic formulation of this distinction between the "sensed world" and the "real world," coming through Plotinus and Augustine, which in considerable part defined the original orthodoxy of the Roman Catholic Church. . . . [Aristotle] found himself forced to say that the real world is the sensed world, and that there are consequently no ideas in the intellect which are not first given through the senses. . . . this Aristotelian thesis seemed to the churchmen in Abèlard's time tantamount to pulling God and Christ's divinity down into the gutter. (Northrop, 1946, pp. 263-264)

The very foundations of the Roman Catholic Church were shaken. The translation of Aristotle and other Greek naturalists into Latin prompted a legitimation crisis in the church itself and raised new questions which existing dogma could not address.

> [Religious scholars] now found themselves confronted with a comprehensive, orderly, generally convincing philosophic system that accounted for every phenomenon of human experience on the basis of reason alone. It posed a challenge of the same kind as that met by the early Fathers—to show that the Christian faith was not at odds with, but was a necessary addition to, human reason. Establishing a harmony between faith and reason, between Christian theology and Aristotelian philosophy, became the main concern of theologians during the next few centuries. (Donner, Eble, & Helbling, 1967, p. 314)
>
> Nevertheless, as the centuries following the coming of the Arabs to Spain passed and European scholars generally, such as Albertus Magnus, became more and more acquainted with the original Greek scientific and philosophical treatises, and were therefore brought face to face with the fact that the Platonic [idealistic] science had broken down in Greek times before indisputable mathematical evidence and had been replaced by the Aristotelian [naturalistic] science, even Catholic scientists and theologians and the church itself were forced to give way to the Aristotelian scientific influence. (Northrop, 1946, p. 264)

As Kuhn might predict, the conditions were thus ripe for the emergence of an alternative worldview.

The scholastic tradition

Science owes its resuscitation at the end of the medieval period to the Roman Catholic Church. The main reason for this "debt" is that all intellectual activity and education throughout the Middle Ages was centered around the church and theology. One of the first challenges to traditional conservative theology occurred in France at Chartres—and was accompanied by other dramatic changes in the new emerging worldview.

> We tend to think that it was the Church as an institution that was blocking serious scientific progress (if not all serious rational thought), but such modern generalizations amount to oversimplifications. Chartres itself was evidently a Church-sponsored cathedral school. The teachers were frocked and robed members of the clergy. The new initiative for the study of science was developed under the protecting hand of one of the most respected bishophrics and cathedral chapters of Medieval France. Since the Church, way into the high Middle Ages, exercised an almost total monopoly over the intellectual life, the situation could hardly have been otherwise. Virtually any important new intellectual movement had to originate in some quarter of a not-as-yet fully centralized (or dogmatically monolithic) Roman Catholic Church. (Goldstein, 1980, p. 76)

According to Goldstein, Chartres "took the lead in reconstructing the scientific knowledge of the Ancient World, thereby establishing a firm basis for the coming evolution of Western science" (1980, p. 76). This move, however, was not without its critics.

> [Early] conservative critics of the new scientific world-view were really little more than that—conservatives, people unable to adjust their thinking to new

> insights and ideas, typical representatives of the inevitable slowness of the human mind. . . . By the thirteenth century, Thomas Aquinas was to show through trenchant philosophical argument that scientific rationalism and empiricism are perfectly compatible with a mystic or religious conception of the world, as long as rationalism remains aware of its metaphysical limitations. That the historic conflict did not end then and there may prove that it was largely nourished by mutual misunderstandings.

Thus, St. Thomas Aquinas, 1225-1274, a Dominican friar, set out to resolve the growing schism between natural philosophy,[18] faith, and authority that resulted from the translation of Aristotle's works into Latin. His explicit goal was to unite reason as a way of knowing with faith and revelation to form a "sacred science" (Aquinas, 1967).

> Sacred doctrine is a science. We must bear in mind that there are two kinds of sciences. There are some that proceed from a principle known by the natural light of the intelligence [i.e., Aristotelian logic], such as arithmetic and geometry and the like. There are some which proceed from principles known by the light of a higher science: thus the science of perspective [i.e., empirical science] proceeds from principles established by arithmetic. So it is that sacred doctrine is a science, because it proceeds from principles established by the light of a higher science, namely, the science of God and the blessed. Hence, just as the musician accepts on authority the principles taught him by the mathematician, so sacred science is established on principles revealed by God. (Aquinas, 1967, p. 317)

The general philosophy of Aquinas followed that of Aristotle—a teleological worldview in which everything exists for the "final cause" of achieving God's intended purpose. Since both origin and final cause of all things are divine, science itself also has to realize its divine origins and ends. Aquinas' first premise is that reason is a

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[18] At this time, natural philosophy began to have the title "science" attached to it. However, note that this "science" still lacked the positivistic methodological characteristics that we define Western normal science by today.

necessary means to understanding worldly purposes and "final ends." He also accepts the necessity of empirical ways of knowing.

> It is befitting Holy Writ to put forward divine and spiritual truths by means of comparisons with material things. For God provides for everything according to the capacity of its nature. Now it is natural for man to attain to intellectual truths through sensible objects [i.e., objects perceived through the senses], because all our knowledge originates through sense. Hence in Holy Writ spiritual truths are fittingly taught under the likeness of material things. (Aquinas, 1967, p. 325)

These first two premises form the basic tenets of Aristotelian science. However, Aquinas also adds a third premise in his search for a common ground between science and theology: the importance of revelation and faith as primary ways of knowing.

> It was necessary for man's salvation that there should be a knowledge revealed by God, besides philosophical science built up by human reason.... Certain truths which exceed human reason should be made known to him by divine revelation.... Although those things which are beyond man's knowledge may not be sought for by man through his reason, nevertheless, once they are revealed by God they must be accepted by faith. (Aquinas, 1967, p. 316-317)

Found within the secular context of Aquinas' writings is the this-worldly contention that nature is orderly, predictable, and understandable. This, combined with logical and empirical ways of knowing, formed the crack in which Science seeped back into the general worldview of the West. This move by the church allowed for one more thing that had been absent for the duration of the medieval period: freedom of thought and the possibility of competing ways of knowing. Much like the Classical period in Greece where aesthetics, logic, sensual empiricism, affectivity, and other ways of knowing formed a broad and rich cultural base, the road paved by Aquinas led to a Renaissance of culture, science, and a rich variety of ways of knowing and understanding the world and man's place in it.

The Renaissance and a diversity of knowing and being

The focus on individual reasoning and responsibility (combined with a certain balance between empirical observation and revelation) as the way to spiritual enlightenment ushered in a new emphasis on this-worldly individualism. This focus on and acceptance of individual—as opposed to other-worldly metaphysical—concerns evolved into the primary philosophical doctrine of the Renaissance: humanism. Humanism is concerned with the study of this-worldly human endeavors and accomplishments (i.e., the humanities), "a conscious return to classical ideals and forms, and a rejection of medieval religious authority" (Concise Columbia Encyclopedia: Microsoft Bookshelf Edition, 1992). It was during this period that sense experience may have reached its peak as a primary way of knowing. The Renaissance is often called the "Age of Adventure" or "Age of Discovery" (see Santillana, 1956). During this period

> between 1450 and 1550, America is discovered [by Europeans], together with the Pacific and South Atlantic oceans, the world is circumnavigated and its real size understood; the Copernican theory denies the common idea of a well enclosed universe with the Earth at the center; the Reformation breaks out all over Western Europe; and 20 million volumes come out of the presses to replace handwriting. (Santillana, 1956, p. 9)

In one sense the most important discovery of the time was not man's discovery of the world, but instead, man's [re]discovery of himself. Renaissance philosopher Pico, 1463-1494, succinctly outlined the humanist worldview in his assertion that

> The true distinction of man . . . [is that] he has no fixed properties but has the power to share in the properties of all other beings, according to his own free choice. He is a universal and protean agent of transformation, hence it behooves him to orient his soul properly towards the good, so as not to use his powers wrongly. (Pico, in Santillana, 1956, p. 15)
>
> At last it seems to me I have come to understand why man is the most fortunate of creatures and consequently worthy of all administration and what precisely is that rank which is his lot in the universal chain of Being—a rank to be envied not only by brutes but even by the stars and by minds beyond this world. It is a matter *past faith* [italics added] and a wondrous one. Why should it not be? For it is on this very account that man is rightly called and judged a great miracle and a wondrous creature indeed. . . . To him it is granted to have whatever he chooses, to be whatever he wills. (Pico, 1967, pp. 425-426)

With Pico and other Renaissance humanists one finds a shift from the medieval focus on predestination and other-worldly concerns to a sensual this-worldly appreciation for man and his potential works. Several great thinkers of the time dealt heavy blows to the medieval worldview and authority of the church.

Erasmus, 1466-1536, the great humanist, dedicated the larger part of his life to an advocacy of human free will and individual responsibility. Martin Luther, 1483-1546, the "Great Reformer" of the church and initiator of the Reformation movement, asserted the importance of this-worldly responsibility, but disagreed with the free will assertions of the humanists.[19] Luther saw faith and reason as incompatible ways of knowing. According to Luther, "You cannot accept both the Bible and reason; one or the other must go" (Luther, in Donner, Eble, and Helbling, 1967, p. 604). Indeed, across the West, faith in the church was progressively deteriorating. Concurrently, Copernicus, 1473-1543, proposed the heliocentric model of the solar system in which mankind is found, not in the center, but on the edge. This violated not only the scriptures but also the highly esteemed and orderly Earth-centered celestial spheres of Aristotle and Ptolemy (even so, the heliocentric model was still not accepted due to the still-growing influence of and respect for Aristotle and his writings). The removal of man from his divine center in the universe was the final blow to the authority of the church and opened the way for this-worldly secular humanism as a predominant worldview. Such a worldview opens a whole new realm of intellectual possibilities previously closed by the other-worldly ideology of the church.

With the freedom of thought and this-worldly focus of the Renaissance worldview, other ways of knowing manifested themselves within the culture of the times. Empirical and kinesthetic ways of knowing combined with aesthetic ways of

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[19] Luther still saw God as the prime mover of men's wills and fates (i.e., predestination and divine order). What Luther sought was to shift "divine truths" from Catholic scripture and ritual to the everyday lives and responsibilities of men. He is often misinterpreted to be a proponent of individualism and free will, but this was an argument against, not for, individual free will and the general secular liberal-humanist doctrine. However, his overt challenge to the authority of the church actually resulted in the further advancement of the humanist movement along side the spread of the Reformation across Europe over the next century.

knowing to create some of the greatest art, music, and architecture ever known. Aesthetic and affective ways of knowing also contributed to art, music, and especially romantic poetry.[20] Other-worldly religious faith, authority, and tradition were replaced by a concern for the this-worldly ethical responsibilities of everyday men and women.[21]

Questions about the relationship of man, god, and nature became paramount not only in formal philosophy but to common citizens as well—this was before the fragmentation of knowledge into competing "disciplines" within the modern university system. Thus, the intellectuals of the Renaissance were eloquently versed in the arts, sciences, literature, philosophy, politics, and whatever else took their fancy at the time. Most importantly for the emergence of the Classical scientific paradigm, logic and reason became the accepted methods for the pursuit of knowledge about the world. Given that the primary epistemological shift in the Renaissance was from detached sanctimony to this-worldly aestheticism and sensuality, it follows that the logical way of knowing would attach itself to empirical-kinesthetic means of understanding. This is indeed what happened. The result was the "dawn of modern science" (Goldstein, 1980).

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[20] Science itself profited greatly from the technical advances made in art—especially the scientific areas of anatomy and geography (see Goldstein, 1980, pp. 188-241).

[21] This-worldly ethical responsibility was the one thing that Luther and humanists agreed on.

Renaissance science was not limited to the modern day components of logic and empiricism. Renaissance science also relied heavily on revelation, aesthetic, and affective ways of knowing. In particular, the science of this period was closely tied to art.[22] This is best illustrated by the work and life of Leonardo da Vinci, 1452-1519.

Da Vinci remained on the fringes, if not outside the mainstream, of scientific thought (Goldstein, 1980, p. 231; Santillana, 1956, pp. 67-68). He lacked academic training and maintained an almost child-like fascination with nature and aesthetics.

> His indefatigable endeavor surveys the whole terrain of experience in search of the outline of a science as yet dimly seen but which he thinks can be eventually grasped only from the whole. (Santillana, 1956, p. 70)

Da Vinci was obsessed with the "nature" of things and how we, as acting human beings, come to understand and appreciate them.

> Who would believe that so small a space could contain the images of all of the universe? O mighty process! What talent can avail to penetrate a nature such a thine? What tongue will it be that can unfold so great a wonder? (Da Vinci, in Santillana, 1956, p. 84)

With da Vinci, science becomes irreversibly grounded in empirical observation. He is known to have solved various engineering problems experimentally through model building (Mason, 1962, p. 149). The scientific manner of thought drove da Vinci and all his work. He sought to understand and capture "reality" as it is experienced, and then represent that reality in such a way that others might experience and understand it in the same fashion.

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[22] Art is typically understood as the result of combining aesthetic and affective ways of knowing. This combination typically relies on an empirical-kinesthetic or sensual process of creation.

> Perception and creation went hand in hand. So did his science and art: he sketched while jotting down observations, often to illustrate a point. Frequently his notes related directly to his painting, in that he desired a more minute understanding of visual phenomenon—the way the sunlight's reflection on a leaf depended on the leaf's transparency; the way a shadow is cast over an object or human face; the structure of a particular bone. The observer of nature was helped by the painter; the artist by the scientist. (Goldstein, 1980, p. 237)

Da Vinci also recognized that mathematics could be used to describe reality. He is quoted (in Santillana, 1956, p. 78; also Mason, 1962, p. 149) as saying "There is no certainty where one of the mathematical sciences cannot be applied." In spite of his lack of a formal education and his general rejection by scientific peers,[23] da Vinci epitomized what would become the "scientific mind" of the Classical paradigm.

> He was the culmination of the continuous Medieval and Renaissance tradition of science, as well as the first brilliant example of the modern scientific mind. More than anyone else, Leonardo, with his universal approach to the world, embodies the evolution of scientific thought from its medieval beginnings via the Renaissance to the present. (Goldstein, 1980, p. 239)

If the first modern scientific mind is attributed to da Vinci, the modern scientific method must surely be attributed to Galileo.

Galileo Galilei, 1564-1642, is sometimes referred to as the "father of modern science" (Capra, 1991, p. 22). According to Einstein and Infeld,

> The discovery and use of scientific reasoning by Galileo was one of the most important achievements in the history of human thought, and marks the real beginning of physics. (Einstein & Infeld, 1938, p. 6)

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[23] He was rejected for a variety of reasons. Within the literature one finds that he was openly criticized for his pauper background, his lack of academic credentials, and also his failure to publish any significant scientific treatises. He had a few unusual habits including a paranoia which prompted him to write everything backwards such that a mirror was required to read it. Accusations of homosexuality and heresy also tarnished the man's reputation as a scholar and scientist. (And all these accusations flourished without a tabloid press!)

Galileo was the first to consistently rely on experimentation in his rational-scientific pursuits. He is referred to by Brownowski & Mazlish (1962, p. 119) as the "first leader of practical science and pioneer of the empirical method." Galileo anticipated Newton's laws of motion and, using the telescope which he invented, found irrefutable empirical evidence for Copernicus' heliocentric model of the solar system (in spite of the fact that, to save his own life after being accused of heresy by the still-powerful church, Galileo would later be forced to recant his support for the model). He made many contributions to science, particularly in the areas of astronomy and physics, but his most significant contribution to the Classical paradigm was undoubtedly his insistence on empirical experimentation as the foundation of the scientific method. Galileo, however, was not the sole originator of the scientific method during this period.

In France, René Descartes, 1596-1650, attempted to create a science based on pure mathematical deduction, or *mathesis universalis*. According to Descartes, there is a strict separation between the objective and subjective worlds.

> Ultimate or ontological reality, according to Descartes, consists of substance. . . . It is in reference to created substances, man and the universe [in contrast with God, which is taken a priori and makes "reality" possible], that Cartesian Metaphysical Dualism applies. That is to say, the ultimate universe is composed of two distinct and separate entities: mind and matter, or soul substance and corporeal substance (thinking substance and bodily substance). . . . Corporeal substance has the quality of filling space, spatiality, while thinking substance (soul, mind) has the quality of (non-spatial) consciousness. Whatever exists must be either one or the other, and whatever is not conscious must be spatial, and vice versa, so that everything is either body or mind, spatial or conscious. (Sahakian, 1968, pp. 137-138)

This assertion had important implications for the Classical scientific paradigm.

> The 'Cartesian' division [between mind and matter] allowed scientists to treat matter as dead and completely separate from themselves, and to see the material world as a multitude of different objects assembled into a huge machine. (Capra, 1991, p. 22)

Given that all reality is either object or subject, thing or thought, matter or mind, Descartes concluded that "the only thing that can be esteemed true is that there is absolutely nothing certain" (Descartes, 1641/1961, p. 37). Thus science, according to Descartes, should start from the point of pure reason, since

> it is now manifest to me that bodies themselves are not properly perceived by the senses nor by the faculty of imagination, but by the intellect alone; and since they are not perceived because they are seen and touched, but only because they are understood [or rightly comprehended by thought], I readily discover that there is nothing more easily or clearly apprehended than my own mind. (Descartes, 1641/1961, p. 42)

According to Descartes, if the starting point of the scientific method is in the intellect, the scientific process much follow a deductive course.

> Thought, in the form of critical doubt, was the only tool the scientist could trust. In solving problems, the simplest possible solution should be examined first and after that the more complex. Straight lines should be postulated before curves. In thinking through a problem, Descartes used the analytical approach. He imagined the problem solved and looked at the consequences of the solution. In doing so, he would quickly realise whether his solution had been right or wrong. (Burke, 1985, p. 155)

Descartes distrusted the senses and placed the emphasis of science on reason and logical deduction. This formed the primary assumption of the Renaissance philosophical system referred to as *rationalism*.

> The Rationalist philosophy of Renaissance Continental Europe held that truth is derived from reason, that reason is superior to, as well as independent of,

> sense experience, and that knowledge is deducible from a priori concepts or necessary ideas. (Sahakian, 1968, p. 132)

Descartes also created a new language for the expression of these logical relationships in the objective world: analytical geometry. Thus, from Descartes, the Classical scientific paradigm acquired several essential attributes. These include the focus on analytical reasoning and mathematics, the strict separation of objective and subjective phenomena[24] (i.e., metaphysical dualism), and a renewal of the Aristotelian deductive method which could now be adapted to quantitative analysis. Meanwhile, the scientific method in Great Britain was being formulated on more pragmatic and empirical foundations.

William Gilbert, 1544-1603, as court physician to Queen Elizabeth I and James I, pursued complex scientific experiments with electricity and magnetism. Gilbert was the first to distinguish between electricity and magnetism, coining the term *electricity* circa 1600. Gilbert is known for his meticulous experimental procedures, the use of controls, and his reliance on empirical data. The Lord Chancellor of England under James I, Francis Bacon, 1561-1626, is also well known for his writings on the scientific method. His primary goal was to unite the existing craft traditions with the scholarly tradition, based on empirical experimentation (Mason, 1962, pp. 141-142). Bacon was philosopher, not a scientist (Mason, 1962, p. 141). His first major work, *The Advancement of Learning* (1605), analyzed

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[24] Previously referred to herein as a symptom of ontological "schizophrenia."

philosophy and the scholarly tradition from the Early Greeks through the scholastic period. In the preface to his unfinished and unpublished work *The Great Instauration* (circa 1620, reprinted in Kaufmann, 1961, pp. 3-9), Bacon lays out his famous method of induction based on an unyielding empiricism.

> Now what the sciences stand in need of is a form of induction which shall analyze experience and take it to pieces, and by a due process of exclusion and rejection lead to an inevitable conclusion . . . not merely out of the depths of the mind but out of the very bowels of nature. . . . I have sought on all sides diligently and faithfully to provide helps for the sense—substitutes to supply its failures, rectifications to correct its errors; and this I hope to accomplish not so much by instruments as by experiments. For the subtlety of experiments is far greater than that of the sense itself, even when assisted by exquisite instruments; such experiments, I mean, as are skillfully and artificially devised for the express purpose of determining the point in question. To the immediate and proper perception of the sense therefore I do not give much weight; but I contrive that the office of the sense shall be only to judge of the experiment, and that the experiment itself shall judge of the thing. (Bacon, in Kaufmann, 1961, pp. 5-6)

Bacon's assertion was that experimentation could overcome the limitations of the senses, in addition to the limitations of logic alone. Bacon (1605/1973, pp. 33-34) openly spoke out against the "mixing" of different ways of knowing in the name of science. He spoke specifically of Plato's confounding of logic and theology, Aristotle's failure to distinguish between logic and philosophy (i.e., revelation), and the overall tendency to confuse true (i.e., inductive and empirical) knowledge with history and authority. Bacon concluded that the only true knowledge is knowledge derived through empirical experimentation—knowledge turned back on itself to press for empirical proofs of its own validity. Like Descartes, Bacon separated the objective from the subjective and located the human mind outside of the “real” objective world. He also correctly identified the two ways of knowing which would form the basis of the Classical scientific paradigm: empirical-kinesthetic and logical-rational. Bacon’s method would supposedly unite these ways of knowing as the direct result of experimentation—thus minimizing the inherent limitations of the senses and the intellect when taken and applied in isolation of each other.

> The method of obtaining hypotheses from tables of facts could be applied, he thought, to hypotheses themselves to get axioms of wider generality. At each stage of the process the hypotheses, axioms, or theories were to be tested experimentally, and applied to human uses if suitable.... Bacon’s view of the scientific method was essentially experimental, qualitative, and inductive. (Mason, 1962, p. 145)

Mathematical descriptions were the only element of the Classical paradigm not found in the work of Bacon. This is probably due to the fact that he was more versed in philosophy than in the natural sciences, however, he did have strong attachments to the craft tradition. Bacon proposed qualitative and logical proofs other than mathematical ones (Galileo, in Italy, and Descartes, in France, would more than compensate for Bacon’s quantitative shortcomings). Bacon’s empirical-inductive methodology still forms the definitive basis of science as it is practiced today, particularly in its positive forms. The practical positivist in Bacon saw science as the tool to free man from the limits of nature. Nature appeared as a negative force to be conquered and scientific knowledge could provide the means by which man could wield the power to do so (Bacon, 1605/1973, pp. 56-57).

> [The] commandment of knowledge is et higher than the commandment over the will; for it is the commandment over the reason, belief, and understanding of man, which is the highest part of the mind, and giveth law to the will itself. For there is no power on earth which setteth up a throne or chair of state in the spirits and souls of men, and in their cogitations, imaginations, opinions, and beliefs, but knowledge and learning. (Bacon, 1605/1973, p. 57)

These ideas of the redeeming social value of science and knowledge formed the core philosophy and ideology of the Enlightenment.

Although the Renaissance era and the emerging scientific perspective resulted directly from a diverse culture sympathetic to several different ways of knowing and understanding, by the end of the Renaissance, humanism was being transformed into scientific positivism, relying primarily on empirical and logical-rational ways of knowing and understanding. By the end of the Renaissance, the Classical scientific paradigm had nearly all of its assumptions laid out. These included an almost exclusive reliance on empirical and rational ways of knowing, a reliance on experimentation and proof as its primary methodology, and the systematic reduction of nature to mathematical relationships and forms as its goal. With the removal of the subjective from the "real world," many ways of knowing (e.g., affective-emotive, aesthetic, faith, history and tradition) were placed outside of—if not antithetical to—the new science. The rich Renaissance culture and sensual humanism that had spawned science from a multitude of ways of knowing now sought to separate the mind from the body, object from subject, and man from nature. Even so, the goal of the new science was emancipatory. Emancipatory not in the sense of saving man from man, but to release man from the reigns of nature, which was now an enemy to be conquered both intellectually and pragmatically.[25] Only one thing was lacking: a comprehensive scientific theory which explained, for man's benefit, the workings of nature once and for all. At the end of the Renaissance and dawn of the Enlightenment, Sir Isaac Newton would provide that final component.

Newton and the crystallization of normal science

Sir Isaac Newton, 1642-1727, mathematician, physicist, academician, and President of the highly esteemed Royal Society for 24 years, is "considered by many to be the greatest scientist of all time" (Concise Columbia Encyclopedia: Microsoft Bookshelf Edition, 1992). Einstein and Infeld (1938), though they attribute the title of "first scientist" to Galileo, award Newton the distinction of being the originator of the mechanical (i.e., Classical) scientific worldview.

Newton's mechanical approach first assumed that the universe, being created by God, was an orderly place operating in accordance with predetermined "natural laws." The goal of the scientist was to empirically seek out and understand these

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[25] Note the shift in world view from one of almost childish curiosity about nature found at the beginning of the Renaissance to one of dominance and control over nature which predominates at the end of the period.

laws, aiming for the ability to predict future occurrences based on mathematical and empirical knowledge of what has happened in other cases.[26]

> In his discussion of the scientific method Newton adopted the view that the starting point for physico-mathematical deductions should be experimentally observed effects or laws and that the deductions should lead to the explanation or prediction of other observable effects. . . . Newton thus specified that it was the observed effects and laws of mechanical motion which should serve as the starting point for mathematical demonstrations in natural philosophy. . . . explaining the unknown in terms of the known was explicit in Newton's work. (Mason, 1962, p. 202)

Newton proceeded to answer all the persistent questions of natural philosophy in an orderly and elegant manner, including the age-old problems of matter, motion, heat, light, etc. Newton's conclusion was that time, space, matter, and motion were measurable, predictable, absolute quantities working (like a clock) in accordance with predetermined natural laws. These laws could be expressed and understood mathematically and arrived at through empirical observations guided by logical deductions. This Classical scientific worldview has "persisted right down to the twentieth century" (Mason, 1962, p. 207). It could be said that all science up to the time of Maxwell and Einstein (and most thereafter) is no more than an addendum to Newton and Newton's empirical, mathematical, and logico-deductive method.

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[26] Newton tended to follow the deductive, mathematical, empirically grounded path set by Galileo other than that pioneered by Descartes (deductive, mathematical, logically grounded) or that of Bacon (inductive, qualitative, empirically grounded). Newton, however, did subscribe to Descartes' "machine view" of the universe and, whether admittedly or not, most often began with hypothetical situations (i.e., grounded only in logic) as opposed to strictly empirical (i.e., grounded specifically in sense data). See Mason (1962, p. 202-207) and also Burke (1985, pp. 159-161) for lively discussions as to the admitted and probable influences of Descartes and Galileo on Newton and Newton's scientific method.

Normal science and positivist thought in the Enlightenment

According to McKay, Hill, & Buckler, "The scientific revolution was the single most important factor in the creation of the new world-view of the eighteenth-century Enlightenment" (1983b, p. 639). Enlightenment thought was characterized by three central concepts: (a) the predominance of the logical-rational way of knowing in the form of natural science, (b) the belief that the scientific method could be applied to the discovery of "natural laws" in both nature and society, and (c) the belief in and pursuit of *progress* through social and scientific engineering.

> The most important and original idea of the Enlightenment was that the methods of natural science could and should be used to understand all aspects of life. This was what intellectuals meant by *reason*, a favorite word of Enlightenment thinkers. Nothing was to be accepted on faith. Everything was to be submitted to the rational, critical, "scientific" way of thinking. . . . A second important Enlightenment concept was that the scientific method was capable of discovering the laws of human society as well as those of nature. Thus was "social science" born. Its birth led to the third key idea, the idea of progress. Armed with the proper method of discovering the laws of human existence [i.e., science], Enlightenment thinkers believed it was at least possible to create better societies and better people. (McKay, Hill, & Buckler, 1983b, p. 639)

John Locke, 1632-1704, was one of the most recognized of the Enlightenment thinkers. Locke rejected the philosophical Rationalism of Descartes and his followers which asserted that certain truths exist *a priori* and can be logical deduced in the absence of empirical sensory experiences. Locke, instead, constructed what is called British Empiricism. Locke thought that the mind, at birth, was a *tabula rasa*, or blank slate. In other words, there are absolutely no *a priori* concepts that originate or exist outside of sensory experiences.

> Let us suppose the mind to be, as we say, white paper, void of all characters, without any ideas; how comes it to be furnished? Whence comes it by that vast store, which the busy and boundless fancy of man has painted on it with an almost endless variety? Whence has it all the materials of reason and knowledge? To this I answer, in one word, from EXPERIENCE; in that all our knowledge is founded, and from that it ultimately derives itself. Our observation, employed either about external sensible objects, or about the internal operations of our minds, perceived and reflected on by ourselves, is that which supplies our understandings with all the materials of thinking. These two [i.e., sensation and self-reflection on those sensations] are the fountains of knowledge, from whence all the ideas we have or can naturally have, do spring. (Locke, 1690/1961, p. 193)

Locke disagreed with the logical-deductive methodology of Descartes and the Rationalists, but followed their general assertion that "Ideas are within us, whereas real things are outside of us and possess the [real] powers or qualities which excite our ideas" (Sahakian, 1968, p. 155). Irish philosopher George Berkeley, 1685-1753, transformed Locke's empiricism to an extreme which identified all "reality' with sense experience itself. Berkeley denied the validity of Locke's "reflective" way of knowing, equating reflection with simple sense-experience, only in the passive as opposed to active sense. Berkeley also refused to accept Locke's view that physical objects "cause" those sensations. However, other than systematically addressing the epistemological problem of how we arrive at these experiences, Berkeley fell back on faith in God as the originator of all that "is."[27] David Hume, 1711-1776, was also considered one of the great British Empiricists. Hume accepted the "realness" of sense experience from both Locke and Berkeley, but, as a true skeptic, rejected all metaphysical sources of knowledge other than direct sense experience. In one sense, Hume could be thought of as the father of positivism, since "the theory that there is no genuine substance or ultimate reality beyond the phenomena of sense is a central concept of positivism" (Sahakian, 1968, p. 162).

The emerging Classical scientific paradigm tended to follow the positivist approach to science (of Bacon, Berkeley, and Hume), relying almost exclusively on empirical observation and denying other ways of knowing and understanding (Concise Columbia Encyclopedia: Microsoft Bookshelf Edition, 1992). To Bacon, objective things outside our minds *cause* our perceptions of those things, which, for the most part, are fairly reliable perceptions. To Locke, objective reality emerged when a person connected the perception of a thing with the thing itself—particularly the *primary* qualities of an object.

> The *primary* qualities of an object are those qualities it has "in itself" quite apart from any perception, qualities it wouldn't have even if there were no sentient being to perceive them. These are, in general, the qualities that can be dealt with in science—those that can be measured. (Hospers, 1967, p. 497)

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[27] Newton's epistemological basis for his own method was very similar to Berkeley's—things exist because God intended them to exist. Of course, faith makes allowances for tautological definitions (e.g., all natural order derives from God; the existence of God is proven by the existence of natural order) and also teleological fallacies (e.g., things exist because it is God's intention that they exist; this is to fulfill his "divine purpose"). Logic, of course, must reject all teleology and tautology. This is but another symptom of schizophrenia in the Classical paradigm.

Locke's brand of empirical positivism is often called *representative realism.*—the idea that sense data form ideas which represent some external reality which exists independent of any perception of it. To Berkeley, the epistemological problem of how we know precluded the acceptance of a reality existing independent of the observer.[28] Berkeley is often referred to as an idealist. Idealism is defined as "accounting for all experience and reality as a direct product of the mind" (Concise Columbia Encyclopedia: Microsoft Bookshelf Edition, 1992). Upon careful examination, however, Berkeley appears to have turned idealism on its head in that he accounts for everything in the mind as a direct product of empirical experience, and thus equates perception with objective reality, as opposed to what might otherwise be considered to be "subjective" reality. In that Berkeley's "reality" is grounded first in sense data, he can also be considered a positivist (see Hospers, 1967, pp. 493-530). The bottom line for Berkeley was not whether there was an objective reality "out there" to be known, but how we come to know what we do and what the limits of that knowledge are. The positivist approach endeavors to explain that reality strictly in terms of sense data and sense impressions. The positivist agenda, however, as initiated first by Hume (and to some degree, by Bacon) and its influence on science and the scientific method took the cruder form of naive realism. Naive realism takes objective reality *a priori*. Matters of religion, relativity, and perception are ignored in

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[28] This will be a central problem in Post-Newtonian science and Quantum Mechanics, which must focus primarily on phenomena working outside the range of human sensory perception.

the naive realist perspective. Hospers (1967, p. 494) identifies the main propositions of naive realism as:

> (a) There exists a world of physical objects (trees, buildings, hills, etc.). (b) Statements about these objects can be known to be true through sense experience. (c) These objects exist not only when they are being perceived but also when they are not perceived. They are independent of the perception. (d) By means of our senses, we perceive the physical world pretty much as it is. In the main, our claims to have knowledge of it are justified. (e) The sense impressions we have of physical things are *caused* by those physical things themselves. For example, my experience of the chair is caused by the chair itself.

Naive realism came to form the philosophical assumptions behind positivism and the Classical paradigm during the Enlightenment. This reflected a general shift in world view from philosophical idealism to more practical means and ends. This was, in part, a result of the efforts of the French philosophe Voltaire, 1694-1778, who

> proposed the application of the Newtonian method of analysis to all knowledge. He advocated a concern with how things work and not with their "essence." For Voltaire, as for Newton, the fact came before the principle.... Naturally, Voltaire's attitude to Newton implied the acceptance of Locke's empirical psychology.... introducing the ideas of Newton and Locke was to change substantially the direction of French thought. The French, after Voltaire, wished to deal with "practical" matters. Such problems as the freedom of the will and the nature of grace were dismissed as meaningless. (Bronowski & Mazlish, 1960, p. 249)

It was in France during the Enlightenment that Science became removed from natural philosophy and turned toward more practical ends involving technology and progress in general. Meanwhile, in Germany, Immanuel Kant, 1724-1804, "combined the Rationalist's thesis that truth is attainable through sheer reason with the opposing thesis of the British Empiricists that valid knowledge can be acquired through sensory experience" (Sahakian, 1968, p. 169). The German Idealism of Kant thus maintained the ontological agenda of natural philosophy, while British and French natural philosophy began to separate ontological from scientific concerns.

Underpinning the shift from ontological to practical science in Great Britain and France was the predominance of naive realism, forming the ideological foundation of scientific positivism. Matters of ontology and epistemology were no longer "scientific" concerns for the British and French natural philosophers (now self-proclaimed *scientists*). Natural law soon came to be taken *a priori* instead of as an ontological question. Bacon's agenda to conquer nature was combined with the Enlightenment ideal of progress and then applied to social, economic, and political variables. The Classical scientific paradigm, based on the empirical experimentation and naive realism of Galileo, Bacon, and Newton, was now considered to be the highest form of knowledge and most esteemed way of knowing.[29] Science had conquered nature. The universe was knowable (through science), operated in accordance with predetermined natural laws which could be mathematically deduced, and could thus be predicted. Newtonian science had provided a thorough explanation of the natural world and all that remained was the question of how to use that information about natural laws to make the social world a better place—to

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[29] Granted, counter movements have come and gone, e.g., Rousseau and the Romantic focus on affective-emotive ways of knowing, but none can claim the success and longevity of the Classical scientific worldview.

understand, explain, predict, and conquer *human* nature. Thus, on the heels of the priestly natural sciences, the social sciences followed.

The Classical Paradigm as a Model for the Social Sciences

The crystallization of the Classical scientific paradigm during the Enlightenment was the product of a number of concomitant intersecting developments. The most significant of these developments was the growing acceptance of logic and reason as a primary way of knowing—in this case, at the expense of all other "subjective" ways of knowing and understanding. The other necessary development was the focus on empirical sense data and sensory experience as a primary way of knowing which was inherited from the Renaissance. With Descartes, man became separated from nature and his biological self, and thus the church (now being concerned primarily with souls and salvations instead of first and final causes) could allow *science* to deal with nature without any threat to religious faith and authority.[30] Thus, when Charles Darwin, 1809-1882, returned from his trip on the *Beagle* and announced that man is a natural evolutionary biological product, it was not seen as a religious or ontological crisis but, instead, as another triumph of the new science. The logical and rational Enlightenment mind could easily extend the idea of evolution from species to other human groups, e.g., societies, regions. Bound with the ideals of progress and enlightenment, and well protected under the umbrella

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[30] The separation of this-worldly and other-worldly "realities" were now taken *a priori* also.

of naive realism, social scientists set out to discover and conquer the laws governing the evolution of societies.

Social science, first, had to reconcile the schizophrenia between mind and body inherited from Descartes. "The very possibility of such an objective [i.e., positive] social science, of course, presupposed its accomplishment in the realm of psychology" (Matson, 1966, p. 33). To that end, Thomas Hobbes, 1588-1679, may have been the first social and behavioral scientist.

> For Hobbes . . ., all mental operations were reducible simply to the "motions" of natural events; his psychology was "materialistic, mechanistic, and deterministic throughout"—an uncompromising effort to encompass all aspects of human existence within the iron laws of explanation. (Matson, 1966, p. 31)

With biological evolution as the prime mover of history, people like Hobbes, Herbert Spencer, 1820-1903, and later, the psychological behaviorists, e.g., John Watson, 1878-1958, need not look in the "black box" of consciousness to explain human behavior.

> Sense is Motion in the organs and interiour parts of mans body, caused by the action of the things we See, Heare, etc.; And that Fancy is but the Reliques of the same Motion, remaining after Sense. (Hobbes, 1651/1961, p. 97)

Like the predictable machinery of Newton's universe, human behavior could also be understood, explained, and predicted using simple scientific methods of empirical observation and logical reasoning. This was the explicit goal of John Stuart Mill, 1806-1873, and his assertion that empiricism forms the foundation upon which all knowledge is built. To Mill, the mind was simply a reflection of the empirical world.

> For Mill the human mind was not merely to be likened to a machine; it was in simple fact a machine, neither more nor less—a delicate mechanism whose

> clockwork operations were automatically triggered by physical forces from the outside (sensory stimuli), and kept going by forces no less physical on the inside. It was this straightforward mechanical image of human nature which underlay the ultimate ambition of the philosophical radicals: to construct a science of legislation, and so of politics, resting squarely upon the foundation of the natural sciences. (Matson, 1966, p. 33)

Given the *a priori* assumptions that (a) nature operates predictably like a clock, (b) man is a natural evolutionary product, and (c) evolution is in fact a progressive historical movement, the reasonable conclusion was that human and social evolution could be explained and controlled by using the same scientific methods applied to natural science—i.e., the idea of scientific progress. Progress was indeed the thread weaving throughout the alternative perspectives of the Enlightenment and driving its ideological influence on the emerging social sciences. Progress was also the central theme of the "Founder of Positivism" and "Father of Sociology," Auguste Comte, 1798-1857.

Human progress, from Comte's perspective, involved the evolution of human ways of knowing from superstition. faith, and theological authority to positive (i.e., progressive logical-empirical) science.

> According to Comte, a certain type of society is dying, another being born before his eyes. The dying type is characterized by two adjectives: theological and military. Medieval society was united by transcendent faith as expounded by the Catholic Church. . . . The type being bon is scientific and industrial. This society is scientific in the sense in which the moribund society was theological: the thinking typical of the modern age is that of scientists, just as the thinking typical of the past was that of theologians or priests. Scientists are replacing priests or theologians as the social category providing the intellectual and moral foundation of the social order. The scientists are inheriting the spiritual power of the priests. Spiritual power . . . is necessarily embodied in each age by those who provide the model for the predominant way of thinking

> and the ideas which serve as the [unifying] basis of the social order. (Aron, 1968, p. 74)

Comte clearly saw science as a product of distinct logical and empirical ways of knowing, cast in opposition to traditional ways of knowing such as religious faith and authority (Halfpenny, 1982, p.16). To Comte, this progressive evolutionary movement in human thought was both necessary and inevitable for the advancement of human society. Comte's law of three stages outlined his model of the progressive development of human understanding.

> The law of the three stages consists in the assertion that the human mind passes through three phases. In the first, the mind explains phenomena by ascribing them to beings or forces comparable to man himself. In the second phase, that of metaphysics, the mind explains phenomena by invoking abstract entities like "nature." Finally, in the third phase, man is content to observe phenomena and to establish the regular links existing among them, whether at a given moment or in the course of time. He abandons the search for the final principle behind the facts and confines himself to establishing the laws that govern them. (Aron, 1968, p. 76).

Comte's new order was modern and industrial. Science could be used as a tool to discern the laws of social development so that man could shape them in his own design. Following Bacon's lead, Comte (in Aron, 1968) asserted

> Indeed, from the moment men think scientifically, the chief activity of collectivities ceases to be the war of man against man and becomes the struggle of man against nature, the systematic exploitation of natural resources. (in Aron, 1968, pp. 74-75)

The purpose of positive science, according to Comte, was to guide the course of social and natural development to the greatest benefit of man. His classification of the sciences placed social physics (i.e., *sociology*) in a higher position than the natural sciences. Comte's positive agenda, combining the law of three stages with his classification of the sciences, then becomes clear:

> The method which has triumphed in mathematics, astronomy, physics, chemistry, and biology must eventually prevail in politics and culminate in the founding of a positive science of society, which is called sociology. . . . [Sociology] can simultaneously determine what is, what will be, and what should be. But at the same time, what will be and what should be is justified as conforming to what the philosophers of the past would have called human nature or human destiny, or what Comte called simply the realization of the human social order. (Aron, 1968, pp. 76-79)

Comte's emancipatory vision for a new social order of reason based on positive science was never realized. Though the influence of Comte within sociology is acknowledged by both Emile Durkheim, 1858-1917, and Karl Marx, 1818-1883, the inherent contradictions of a positive science[31] of human nature still plague the social sciences today.

> For Comte no less than for Hegel, man acquired a degree of reason only through submission to the rational processes of society. As the source of reason was thus displaced from the individual to the collective, so liberal-democratic conceptions of personal freedom and responsibility [i.e., free will]

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[31] Halfpenny (1982) pointed out that "positivism" has a variety of connotations in the social sciences. See Halfpenny (1982, p. 114-117) for a summary of twelve different ways in which positivism is understood within the literature. Herein, for the most part, positivism refers specifically to Halfpenny's Positivism$_1$ which he defined as "a theory of knowledge according to which the only kind of sound knowledge available to humankind is that of *science* grounded in observation" (italics added). In one sense, Halfpenny has broken the idea of positivism into different ways of knowing. Halfpenny defined Positivism$_{10}$ as "a theory of knowledge according to which science consists of a corpus of causal laws on the basis of which phenomena are explained and predicted, and Positivism$_{11}$ as Bacon's "theory of scientific method according to which science progresses by inducing laws from observational and experimental evidence" (1982, pp. 114-115). The primary difference between these different connotations of positivism is the primary way of knowing utilized, i.e., empirical or logical. The other distinction made by Halfpenny is the origin and intent of the exemplar, e.g., derivations made by Comte (Positivisms$_{1-4}$), Spencer's focus on progress and evolutionary forms (Positivism$_5$) Durkheim's addition of statistical methods (Positivism$_6$), and the logical positivists' linguistic focus in Positivism$_8$. He also alluded to what is referred to herein as a schizophrenia in the Classical paradigm between the empirical and logical as well as the ontologically and conventionally "real." Though all these "positivisms" form part of the Classical scientific paradigm, not all are compatible and complementary with each other.

> gave way to an emphasis upon authority and social order—more exactly, upon the efficiency and rationalization of social engineering. . . . It was a tragic vision. The goal of the positive scientists of society was nothing less than the universal enlightenment and emancipation of mankind. But the outcome was otherwise. Science, enlisted in the case of reason, led in the end to the denial and abolishment of reason: "The logic and tyranny of progress gave to the world the progress of total tyranny." The first comprehensive attempt to apply scientific method to the rationalization of human conduct—what might be termed the first systematic program of behavioral engineering—turned out to be, not a dispassionate and positive science of behavior, but a wholly passionate and negative campaign to make men *behave*. (Salomon in Matson, 1966, p. 36)

Even if the emancipatory agenda of Comte's positivism failed miserably, the faith in positive science as an appropriate method for the social sciences lived on.

Durkheim, expanding the positivist scientific approach, would introduce statistics and mathematical methods into sociology and, concomitantly, into education and the social sciences in general. Adam Smith, 1723-1790 applied Newton's machine model to economics and proposed that the market operates in accordance with natural laws (i.e., "the invisible hand") and these laws function for the progressive development of society as a whole (see Heilbronner, 1961, pp. 28-57). Herbert Spencer, 1820-1903, also advocated a positivistic understanding of the natural laws of society (e.g., survival of the fittest) but, unlike Comte, Spencer proposed that nature knew the path of progress far better than man, thus, a *laissez faire* social policy would best serve the interests of individuals and society. Marx formulated a positivistic theory of social change: science and technology would inevitably usher in a socialist utopia after the inherent contradictions of industrial capitalism precipitate its own demise. Max Weber, 1864-1920, documented the historical and positivistic shift in ways of knowing from traditional, faith, and affective-emotive to logical and rational (1921/1978; 1905/1958). Though Weber was mostly critical of crass empiricism and positivism, he still admired the scientific method and proposed that sociology and economics engage in scientific pursuits within a framework of "ethical neutrality" and "objectivity" (1903-1917/1949). Weber proposed that meanings and sentiments could be the *object* of scientific inquiry, but such inquiry necessitates the separation of the observer from what is observed. This Cartesian detachment is a fundamental tenet of the Classical paradigm and still contributes to the schizophrenia of modern science today. Upon examination, one finds that most of the ontological and epistemological assumptions of the social sciences are rooted deeply in the Classical scientific paradigm.

This is not to deny that the Classical scientific paradigm has its critics in the social sciences. The debate may be best described by Halfpenny.

> At one extreme, sociologists have clung to the earlier, simpler solutions to the various epistemological problems, even where these answers are now commonly recognised by philosophers to be inadequate. In other words, they have continued to pursue a programme aimed at constructing a natural science of society centring on causal laws derived from or tested by observational data with the aid of statistical techniques, and they treat the philosophical problems as mere technical difficulties. . . . Among this group of statistical technicians, doubts about positivist presuppositions in social analysis are assumed to be resolvable by greater attention to the details of data collection and statistical techniques.
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> At the other extreme, sociologists have taken the philosophical problems as grounds for rejecting the concerns of positivist philosophers altogether, and they have turned instead to anti-positivist programmes for sociological analysis and research. Indeed, attempts to establish any sort of

> positivist hegemony in sociology have always faced numerous challenges that alternative understandings of the social world [i.e., ways of knowing] are more appropriate to the human nature of its subject matter. *What is of interest here is not whether positivism of some sort is able to disarm or absorb them, but that the challengers take positivism, as their target, still assuming that it is the dominant form of sociology to be discredited and transcended by their preferred alternative* (italics added). (Halfpenny, 1982, p. 120)

Though Halfpenny's conclusion might sound a bit tautological, it is a fact that most social scientists agree that positivism, particularly the positivist belief in methodological neutrality and objectivity[32], forms the primary methodological foundations of the social sciences (see Turner, 1991, pp. 1-4; also Abercrombie, Hill, & Turner, 1988, pp. 190-191, 233-234). Although it does not prove the primacy of positivism in the social sciences, the ongoing debate does lend support for the argument that the Classical scientific paradigm has been a strong ongoing influence on the social sciences.

That influence, for the most part, still endures in the form of the social sciences' methodological detachment, objectivity, and the main ideological tenets of the Classical scientific paradigm: (a) the machine model of the universe built upon the methodological reduction of phenomena to fundamental "building blocks," structural determinism, and mathematical predictability, (b) the separation of mind and body, with the body and its observable behaviors also following the machine

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[32] This is the Cartesian duality of mind and matter. It assumes that the observer can be physically and affectively detached from what is observed. It also assumes that the observer, given adequate experimental controls, will not influence the outcome of events. This point of the Classical paradigm will form part of the "crisis" of normal science as the quantum paradigm begins to emerge.

model with the mind falling outside the realm of "objectivity," and (c) the belief and trust in positivistic progress through science and technology (Capra, 1989, p. 325). In at least one sense, Comte has been proven right—his ranking of the sciences placed the social sciences, i.e., sociology and economics, as last in moving to a the new (then positivistic) scientific paradigm. Is this a case of history repeating itself? The natural sciences are now shifting away from the ontological and epistemological assumptions behind the Classical Newtonian scientific paradigm. This is a result of new findings in science which occurred around the early part of the twentieth century—findings which created a crisis in the classical paradigm which could not be resolved by the methods of normal science. While the social sciences are, for the most part, doggedly clinging to the classical Newtonian worldview, the natural sciences are being forced to question that paradigm. In fact, a new scientific paradigm is emerging. Though no consensus yet exists as to what that paradigm is or what is might be called, for practical purposes, this shift in scientific worldviews will herein be referred to as the Post-Newtonian paradigm.

REVIEW OF THE HISTORY AND PHILOSOPHY OF WESTERN SCIENCE

PART II: THE POST-NEWTONIAN PARADIGM

Determinism to Relativity

The Classical Newtonian paradigm provided the Post-Renaissance world with a comforting picture of the universe. The riddle of matter was solved by the reduction of all substances to finite particles, which could be examined to explain the "fundamental" properties of the whole. Heat was also explained by the movement of elementary particles, as well as the phenomenon of light. Motion and stability were explained by the relationship between the force of gravity, mass, and distance, which also provided a secular "cause" for the existence of the planets and their apparently orderly behavior. Nature operated in accord with natural laws, which directed the evolutionary process in the direction of positive progress. These universal regularities could be observed empirically, modeled mathematically, and then used to man's advantage in predicting and controlling the outcome of future events. The universe was a marvelous clock, operating for the benefit of mankind, which stood at the pinnacle of the evolutionary scale of progress. Thanks to Newton, the universe was a wonderful place indeed.

Thus, it was probably with considerable trepidation that Einstein announced the fall of the Classical mechanical worldview.[33]

> There are no eternal theories in science. It always happens that some of the facts predicted by a theory are disproved by experiment. Every theory has its period of gradual development and triumph, after which it may experience a rapid decline. The rise and fall of the substance [i.e., particle] theory of heat . . . is one of many possible examples. . . . Nearly every great advance in science arises from a crisis in the old theory, through an endeavor to find a way out of the difficulties created. We must examine old ideas, old theories, although they belong to the past, for this is the only way to understand the importance of the new ones and the extent of their validity. (Einstein & Infeld, 1938, p. 75)

The cracks in the Classical Newtonian universe began with the discovery of the relationship between magnetism and electricity. Originally, magnetism and electricity were explained by a mechanical "fluid" theory, i.e., they (in addition to heat) were viewed as moving substances comprised of unique and identifiable fundamental particles in themselves. The classical paradigm's demise began with early experiments in electromagnetism, starting with Gilbert in the seventeenth century, and progressing through Franklin's Leyden jar, Volta's voltaic cell, and Oersted's[34] discovery that the flow of electricity can affect the attractive properties of a magnet and vice versa (now the basis for electrical motors and generators). The behavior of the "substances" in these experiments did not lend credence to the fluid (i.e., particle) theory of magnetism and electricity. Einstein lamented that

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[33] This passage from Einstein probably influenced Kuhn and his ideas about the rise and fall of scientific paradigms.

[34] Benjamin Franklin, 1706-1790; Allessandro Conte Volta, 1745-1827; Hans Christian Oersted, 1777-1851.

> Difficulties of this kind, sudden and unexpected obstacles in the triumphant development of a theory, arise frequently in science. Sometimes a simple generalization of the old ideas seems, at least temporarily, to be a good way out. It would seem sufficient, in the present case, for example, to broaden the previous point of view and introduce more general forces between the elementary particles. Very often, however, it is impossible to patch up an old theory, and the difficulties result in its downfall and the rise of a new one. (Einstein & Infeld, 1938, p. 90)

Often, as Einstein pointed out (*ibid.*), scientists prefer to add stipulations and/or additional components to their theories other than give them up. This was also the case with the mechanical theory of light. Scientists following the mechanical model, naturally, treated light as a fundamental particle (which they called a corpuscle). The problem which Newton addressed was the problem of color. If light is a particle, how can it give the appearance of an infinite number of colors? Newton modified the corpuscular theory to account for color by proposing that each color of light is a different type of corpuscle. According to Newton, a prism "sorts" the corpuscles into distinct groupings which can then be "regrouped" if directed through a second prism. The idea of light existing as waves is also part of the Classical mechanical paradigm, though not supported by Newton. Christian Huygens, 1629-1695, proposed a wave theory of light but, like Newton, had to add some stipulations and additional components to the existing mechanical model. Being that waves require a medium within which to travel, Huygens asserted that space was not a vacuum, but was composed of ether, a universal medium within which light can make its journey.[35] Both Newton and Huygens had empirical evidence in support of their model. What was inadequate, however, was the mechanical approach itself. Still, it would take over a century to resolve these crises in the Classical paradigm.

As Einstein summarized:

> In the old theories of electric fluids, in the corpuscular and wave theories of light, we witness the further attempts to apply the mechanical view. But in the realm of electric and optical phenomena we meet grave difficulties in this application. (Einstein & Infeld, 1938, p. 122)
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> A moving charge acts upon a magnetic needle. But the force, instead of depending only upon distance, depends also upon the velocity of the charge. . . . In optics we have to decide in favor of the wave theory against the corpuscular theory of light. Waves spreading in a medium consisting of particles, with mechanical forces acting between them, are certainly a mechanical concept. But what is the medium through which light spreads and what are its mechanical properties? There is no hope of reducing the optical phenomena to the mechanical ones before this question is answered. But the difficulties in solving this problem are so great that we have to give it up and thus give up the mechanical view as well. (Einstein & Infeld, 1938, p. 122)

In the same manner that Newton challenged the paradigm put forth by Aristotle in regard to motion, light, and matter, late-nineteenth century scientists such as Oersted, Faraday, and Maxwell[36] challenged Newton's mechanical model. It was Maxwell and the identification of non-material *fields* that shattered the mechanical-particle assumption of the universe inherited from Newton.

> In Maxwell's theory there are no material actors. The mathematical equations of this theory express the laws governing the electromagnetic field. They do not, as in Newton's laws, connect two widely separated events; they do not

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[35] Chemistry also had a universal medium which it called *phlogiston*, allowing for the loss of weight when a substance is burned.

[36] Michael Faraday, 1791-1867; James Clerk-Maxwell, 1831-1879.

> connect the happenings *here* with the conditions *there*. The field *here* and *now* depends on the field in the *immediate neighborhood* at the time *just passed*. The equations allow us to predict what will happen a little further in space and a little later in time, if we know what happens here and now. They allow us to increase our knowledge of the field by small steps. We can deduce what happens here from that which happened far away by the summation of those very small steps. In Newton's theory, on the contrary, only big steps connecting distant events are permissible. (Einstein & Infeld, 1938, pp. 146-147)

This posed a crisis with the mechanical assumptions behind the Classical paradigm. To exacerbate the crisis, the Classical Newtonian model was flanked on more than one side.

There are really two revolutions in paradigmatic thought that occur with Maxwell's theory. First, explicit in Einstein's evaluation (*ibid.*), is the shift from structural determinism to a focus on process. In Newton's clockwork universe, elementary particles behaved in accordance with natural laws—structure was taken *a priori* with process emerging from the structural relationships of the fundamental particles. Now, with Maxwell, there are no fundamental particles to determine how the phenomena will "behave," which, by necessity, shifts the causal mechanism from one of structural properties to one of process.

> The old mechanical view attempted to reduce all events in nature to forces acting between material particles. Upon this mechanical view was based the first naive theory of the electric fluids. The field did not exist for the physicist of the early years of the nineteenth century. For him only substance and its changes were real. He tried to describe the action of two electric charges only by concepts referring directly to two charges. (Einstein & Infeld, 1938, p. 151)

The second paradigmatic revolution of Maxwell is only implicit in Einstein's evaluation—that is the shift from empirical understanding of natural phenomena to logical-deductive methods. In spite of the extensive use of experimentation in ascertaining the nature of electromagnetic fields, the truth remains that such fields are outside of the realm of human sense-experience. A subtle shift in the accepted ways of knowing had to occur for Science to proceed—logic and reasoning had to move ahead of empiricism in explaining natural phenomena. According to Einstein & Infeld (1938, p. 151), "A new reality was created, a new *concept* for which there was no place in the mechanical description" (italics added). When the object of investigation lacks substance, empirical observation must shift from the observation of structural properties to the anticipation of procedural effects. Science in the Post-Newtonian paradigm thus shifted, by necessity, from the study of "objective" reality to the study of the *effects* of that (now imperceptible) reality. As much as this relies on empiricism as a way of knowing, it even more relies on sequential reasoning (even intuition and revelation?) as a primary form of knowing and understanding. After a century of naive realism grounded in the omnipotence of the Classical Newtonian scientific paradigm, the cosmic soup was again being stirred. The man with the ladle was young Albert Einstein.[37]

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[37] Albert Einstein, 1879-1955. Birthdates and dates of death will no longer be provided herein since we are now discussing recent and current history.

Einstein is famous not only for his contributions to physics, but for the nature of those contributions—thought experiments. The problem with the Newtonian paradigm, according to Einstein and Infeld (1938, p. 157), is that it is wholly dependent on some God's eye view of the universe. According to Einstein, the *empirical* nature of reality is always relative to a particular coordinate system (CS), or, in layman's terms, the place of the observer. Famous thought experiments of Einstein illustrate the relativity of empirical reality:

> One way, though by no means the simplest, of not hearing what someone is saying, is to run, with a velocity greater than that of sound, relative to the air surrounding the speaker. The sound waves produced will then never be able to reach our ears. On the other hand, if we missed an important word which will never be repeated, we must run with a speed greater than that of sound to reach the produced wave and catch the word. (Einstein & Infeld, 1938, p. 166)
>
> A bullet fired from a gun actually moves with a speed greater than that of sound and a man placed on such a bullet would never hear the sound of the shot. (Einstein & Infeld, 1938, p. 166)

Einstein gave a new answer to the age old question that "If a tree falls in the forest does it make a sound?" According to Einstein, it is a simple matter of physics and not an ontological issue: regardless of whether there is an observer or not, it still depends on the coordinate system or reference point of the observation. Einstein also extended his relativity theory to the phenomena of light and time. His famous thought experiments with observers both inside and outside sealed moving rooms indicate that

> Comparing the predictions of our two observers we find a most astonishing result which flatly contradicts the apparently well-founded concepts of classical physics. Two events, i.e., the two light beams reaching the two walls, are

> simultaneous for the observer on the inside, but not for the observer on the outside. In classical physics we had one clock, one time flow, for all observers in all CS. Time, and therefore such words as "simultaneously," "sooner," "later," had an absolute meaning independent of any CS. Two events happening at the same time in one CS happened necessarily simultaneously in all other CS. . . . the relativity theory [forces] us to give up this [classical] view. (Einstein & Infeld, 1938, p. 179)

Einstein used the thought experiment of two clocks moving in different CS to illustrate this point further. His unsettling conclusion was that time itself is relative to the point of observation or place of the observer. Another of Einstein's unsettling conclusions destroyed the very foundation of Newtonian physics: the assumption of some underlying material structure of the universe.

> Classical physics introduced two substances: matter and energy. The first had weight, but the second was weightless. In classical physics we had two conservation laws: one for matter and one for energy. We have already asked whether modern physics [i.e., relativity theory] still holds this view of two substances and the two conservation laws. The answer is: "No." According to the theory of relativity, there is no essential distinction between mass and energy. Instead of two conservation laws we have only one, that of mass-energy. . . . The old energy-substance is the second victim of the theory of relativity. The first was the medium through which light waves were propagated [i.e., the ether]. . . . [Relativity theory] removes the difficulties and contradictions of the field theory; it formulates more general mechanical laws; it replaces two conservation laws by one; it changes our classical concept of absolute time. Its validity is not restricted to one domain of physics; it forms a general framework embracing all phenomena of nature. (Einstein & Infeld, 1938, pp. 197-199).

Though Einstein sought to remove the classical "God's eye view" from our understanding of the universe, he did not seek to remove God from the universe. Einstein saw his theory of relativity more as an extension of classical mechanics that takes different reference frames into account— relativity theory was more elegant and less problematic than the Classical paradigm. At no time did Einstein doubt the existence of fundamental laws governing the universe or the classical vision of some divine purpose of it all.

> The simpler our picture of the external world and the more facts it embraces, the stronger it reflects in our minds the harmony of the universe. (Einstein & Infeld, 1938, p. 213)

To Einstein, relativity did not mean uncertainty. In that sense, the Classical paradigm and the assumptions of order behind it lived on in the work of Einstein (Calder, 1980, p. 13). The next leap in physics was to unsettle even Einstein: the move from relativity to Quantum physics. The movement started in a rather typical and inconspicuous manner.

Relativity to Uncertainty and the Quantum Revolution

Fundamentals of the quantum paradigm

Quantum mechanics starts where the Ancient Greeks left off: in search of a fundamental substance which comprises the universe. Recall, Democritus, in Ancient Greece, had proposed that *atoms* (trans. "not" "divisible") were the fundamental buildings blocks of all that exists. Robert Boyle, 1627-1691, the "Father of Chemistry," "used the concept of atoms [i.e., *elements*] in his work on chemistry in the seventeenth century" (Gribbin, 1984, p. 20; Lerner & Trigg, 1981, p. 63). Newton also operated under the assumption of some fundamental particle or substance, such as atoms, in his formulation of the Classical paradigm. (Gribbin, 1984, p. 20; The

Concise Columbia Encyclopedia: Microsoft Bookshelf Edition, 1992). While several attempts had been made to empirically establish the existence of atoms (e.g., Lavoisier; Proust; Dalton; Avogadro)[38] it was not until Einstein's paper on Brownian motion (1906) that real proof of the existence of atoms was offered in a sufficiently convincing manner.

> In 1827, the English botanist, Robert Brown, was observing pollen with a newly improved microscope and noted that the pollen jumped around in a random fashion as if it were alive. He later observed the same random motion using small smoke particles and concluded that the motion was not caused by the smoke particle itself . . . A satisfactory explanation was finally given in 1906 by Einstein (and separately by Smoluchowski) and constituted the most direct proof up to that time of the existence of atoms. (Blood, 1981, p. 93)

Given the challenge to the Classical paradigm posed by electricity and magnetism many of the leading physicists of the era sought to reestablish deterministic laws and principles at the atomic level to affirm their faith in the divine order of the universe. A puzzling problem stood in the way of their lofty goal: the explanation of black body radiation.

Blackbody or thermal radiation is the energy that results from the motion of atoms and molecules (Bedford, 1981, p. 83). All objects emit, and consequently, must absorb, this type of energy in accordance with the laws of thermodynamics.

> The simplest way to see (literally) how matter and radiation interact is to look at a hot object. A hot object radiates electromagnetic energy, and the hotter it is the more energy it radiates, at shorter wavelengths (higher frequencies). So a red-hot poker is cooler than a white-hot poker, and a poker that is too cool to radiate visible light may still feel warm, because it [still] radiates lower-

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[38] Antoine Laurent Laviosier, 1743-1794; Joseph Louis Proust, 1754-1826; John Dalton, 1766-1844; Amadeo conte di Quaregna Avogadro, 1776-1856.

> frequency infrared radiation. Even at the end of the nineteenth it was fairly obvious that this electromagnetic radiation must be associated with the movement of tiny electric charges. The electron itself had only just been discovered, but it is easy to see how a charged part of an atom (which we would now identify with an electron) vibrating to and fro will produce a stream of electromagnetic waves, in a manner not too unlike the way you can make water ripples by wiggling a finger to and fro in your bath. The trouble was that a combination of the best classical theories—statistical mechanics, and electromagnetism—predicted a form of radiation very different from the kind actually observed coming from hot objects. (Gribbin, 1984, p. 35)

Leaving aside the mathematical formulas and getting directly to the point, the Classical approach to blackbody radiation predicts a near-infinite amount of energy at the very shortest (i.e., highest) wavelengths.

> The calculations came from the seemingly natural assumption that the electromagnetic waves of the radiation could be treated in the same way as waves on a string . . . and that there can be waves of any size—wavelength or frequency. (Gribbin, 1984, p. 36)

However, this was not the case. Experiments demonstrated that, at high frequencies, the energy of blackbody radiation is not very large, in fact, at extremely high levels, the energy actually falls back to near-zero levels. What was at stake here was not just the reputation of a few famous scientists. At stake was the assumption at the foundation of the Classical paradigm: structural determinism. If electrons were in fact small charged particles that gave atoms their electromagnetic properties, they should follow the Classical laws of thermodynamics and the energy they radiate should follow the Classical wave patterns laid out by Galileo. This was yet another anomaly in the Classical paradigm which threatened Classical structural determinism. Ironically, it was a German scientist of the old school who first resolved the crisis.

Max Planck, 1858-1947, originally thought he could resolve the crisis by applying the Classical laws of thermodynamics. With complete faith in the Classical model, he conservatively proposed that energy might only be admitted or absorbed by objects in discrete proportions, or *quanta*. This would indeed solve the blackbody problem.

> For very high frequencies, the energy needed to emit one quantum of radiation is very large, and only a few of the oscillators will have this much energy (in accordance with the statistical equations) so only a few high-energy quanta are emitted. At very low frequencies (long wavelengths), very many low-energy quanta are emitted, but they each have so little energy that even added together they don't amount to much. Only in the middle range of frequencies are there plenty of oscillators that have enough energy to emit radiation in moderate-sized lumps, which add together to produce the peak in the blackbody curve. (Gribbin, 1984, p. 43)

Planck's discovery of quanta did not, however, propel quantum theory into the forefront of physics. Another crisis had to occur in the Classical paradigm before the significance of Planck's solution could be fully realized. That was the challenge Einstein posed to the Classical assumption of Cartesian dualism—the separation of mind and matter, subject from object, observer from observation.

After Einstein, the appearance of structure was wholly dependent upon the action of observation, i.e., the God's eye view lost its place in Science. "The chief merit of the name 'relativity' is in reminding us that a scientist is unavoidably a participant in the system he is studying" (Calder, 1984, p. 13). Planck's solution was revolutionary because it called for something that the Classical conception of energy didn't address—conservation of *action*.[39] Einstein's special theory of relativity, which took into account observations of phenomena at high-speed motion, made a conservation of action possible by shifting the basis for "natural laws" from structure to process. Thus, the idea of quanta shifted physics away from structural determinism and led to a focus on *process* as the basis for order in the universe. Though Planck had not realized it, he discovered that the "elementary particles" forming the building blocks of the universe weren't particles at all. They are, instead, abstract *potentials* , *events*, or *processes* which allow matter to take on particular states, much like the outcome of the roll of a die.

It was the final blow to the Newtonian worldview and, as such, opened up a new window from which to witness the workings of the universe. But it was a bizarre picture indeed. As Einstein put it,

> All my attempts to adapt the theoretical foundation of physics to this (new type of) knowledge failed completely. It was as if the ground had been pulled out from under one, with no firm foundation to be seen anywhere, upon which one could have been built. (in Capra, 1991, p. 53)

Sir Joseph John Thomson, 1856-1940, had already discovered the electron by the time Einstein's paper on Brownian motion had been published. According to Pais,

> Ever since its discovery, the electron has been considered an elementary particle, a fundamental building block of matter that cannot be decomposed into more primary constituents.... Lorentz introduced the classical model of the electron: a charge distribution confined (at rest) to a small sphere of a [mathematically definable] radius. (Pais, 1981, pp. 235-236)

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[39] See Gribbin (1981, pp. 35-49) for a more informed discussion of how Einstein took Planck's ideas—particularly the four dimensional "action" or "process" relationship between energy and time given in Planck's constant—and laid the groundwork for the quantum revolution.

Electrons then, in the Classical model, were charged particles, having a definable mass, orbiting atoms in much the same manner as planets in our solar system orbit the sun. This is but a restatement of Newton's corpuscular theory of matter. According to Heisenberg, this approach cannot apply at the quantum level of reality.

> The concepts of velocity, energy, etc., have been developed from simple experiments with common objects, in which the mechanical behavior of macroscopic bodies can be described by the use of such words. The same concepts have then been carried over to the electron, since in certain fundamental experiments electrons show a mechanical behavior like that of objects of common experience. Since it is known, however, that this similarity exists only in a certain limited region of phenomena, the applicability of corpuscular theory must be limited in a corresponding way. (Heisenberg, 1949, p. 13)

The famous double slit experiment demonstrated that electrons and other minutely small "particles" would take on the properties of either a particle or a wave, depending on the experimental context. When passing a single electron through a pinhole, the electron acts like a particle beam and leaves a small round image on a photoelectric plate. However, when another hole is added, the pattern on the photoelectric plate changes to a band of light and dark stripes. This puzzled even Einstein.

> There may be some hope of explaining this phenomenon [of the circular ring] by interaction between the electron and rim [of the hole], though such an explanation does not seem to be very promising. But what about the two pinholes? Stripes appear instead of rings. How is it possible that the presence of the other hole completely changes the effect? The electron is indivisible [in the Classical understanding of it] and can, it would seem, pass through only one of the two holes. How could an electron passing through a hole possibly know that another hole has been made some distance away? (Einstein & Infeld, 1938, p. 279)

Thus, the Classical conception of fundamental particles as the building blocks of the universe had to be abandoned. Even so, physicists of the time still had faith in natural laws and were certain that science could still serve its explanatory and predictive functions for the community. Again, empirical experimentation proved them wrong again.

The proof of the quantum pudding remained in the ability to measure the transformation of mass and energy in accordance with Einstein's' theory of relativity. Both Neils Bohr, 1885-1962, and Werner Heisenberg, 1901-1956, sought to determine and measure the structure of the atom in such relativistic quantum terms. In this attempt it was Heisenberg that pulled the rug out from under any hopes of resolving the crisis between the Classical and quantum paradigms. Heisenberg's discovery became known as the indeterminacy or *uncertainty principle*. The tenets of the uncertainty principle are best explained by Sullivan:

> The principle of indeterminacy is founded on the fact that we cannot observe the course of nature without disturbing it. This is a direct consequence of quantum theory.... An electron in complete isolation would be unknowable. It is only when an electron is interchanging energy with some other part of the universe that we can become aware of its existence [i.e., through process]. But no interchange of energy can take place that does not involve at least one quantum or atom of energy. Now the electron is so small and light a body that this amount of energy is sufficient seriously to disturb it. Let us suppose, for example, that we are observing the electron's position through some sort of super-microscope, so as to calculate where it will be a second hence. In order to see the electron we will have to use light. At least one quantum of energy will be involved, and this is sufficient to disturb the electron in an unpredictable manner. By using light of long wave-length, and therefore of little energy, we would not greatly disturb the velocity of the electron, but its position would be very hazy, since we cannot distinguish objects that are small compared with the wavelength of the light we are using. If on the other hand,

> in order to determine the position accurately, we used light of very short wavelength, its great energy would hopelessly disturb the motion of the electron. Now for accurate prediction we must know both factors; we must know both position and velocity. But these two factors are so connected that the more accurately we know the one the less accurately we know the other. . . . We see, then, that we cannot accurately determine an electron's future behavior. Any observations we make in order to get the necessary data disturb the electron in an unpredictable way, and therefore our data become useless in the very act of obtaining them. What, then, becomes of the determinism hitherto assumed by physical science? It becomes a useless principle. (Sullivan, 1933, pp. 70-71)

Sullivan asserts that Heisenberg's uncertainty principle challenges the very core of the Classical paradigm: determinism and predictability. Heisenberg was willing to take the argument even a step further—to the rejection of causality as a principle in itself.

> As is clear from what has been said, the resolution of the paradoxes of atomic physics can be accomplished only by further renunciation of old and cherished ideas. Most important of these is the idea that natural phenomena obey exact laws—the principle of causality. In fact, our ordinary description of nature, and the idea of exact laws, rests on the assumption that it is possible to observe the phenomena without appreciably influencing them. To co-ordinate a definite cause to a definite effect has sense only when both can be observed without introducing a foreign element disturbing their interrelation. The law of causality, because of its very nature, can [therefore] only be defined for isolated systems, and in atomic physics even approximately isolated systems cannot be observed. (Heisenberg, 1949, p. 63)

So what does this tell us about our preconceptions of the universe? Where does it leave Science as a way of knowing and understanding the ontological world? In fact, there are several interpretations of quantum theory in the literature. Some are fantastic, some are easily anticipated, but none resemble the Classical Newtonian universe we once thought was ours. Different interpretations of the quantum facts lead us to very different ontological understandings of the universe. These various interpretations can be summarized as follows.[40]

Interpreting quantum reality

Summarizing the various ontological interpretations of quantum theory is not an easy task for several reasons. First, the nature of the subject matter is abstract and exceeding complex, rendering it vulnerable to a broad scope of interpretation ranging from science fiction and magic to mundane mathematical mechanisms. Second, most of the primary actors on the quantum stage have changed their own ideas about the ontological meaning of quantum reality, sometimes more than once or twice. Finally, we cannot escape the epistemological problems that have plagued us since the days of the first natural philosophers, i.e., how do we overcome the gap between what "is" and the limits and/or distortions of our perception? In spite of these difficulties, the literature is rich with ontological speculation in regard to quantum reality. Discussed herein are the Copenhagen Interpretation, the Weak Copenhagen Interpretation, the Consciousness Interpretation, the Austin Interpretation, Heisenberg's Duplex Interpretation, the Many-Worlds Interpretation, the Wholeness Interpretation, and two of the several Realist Interpretations or arguments: the Quantum Logic argument and the Reactionary or Hidden Variables argument. The most accepted of

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[40] This classification is taken in part from Herbert (1985) and also Casti (1989).

the various interpretations of the quantum puzzle is also the first on the scene, and perhaps the most discomforting: the Copenhagen Interpretation.

The Copenhagen Interpretation, offered by quantum pioneer Neils Bohr and supported by Werner Heisenberg during his work at Bohr's Institute in Copenhagen, is simply stated: *There is no deep reality.* The first reaction people have to Bohr's statement is that Bohr really means (in the positivist sense) that reality is "fuzzy" and can't be empirically studied therefore people can't conclude anything about it in a satisfactorily scientific manner. To that reaction Bohr replies, with more emphasis (In Herbert, 1985), THERE IS NO DEEP REALITY. This does not, however, mean you should feel safe pulling your Buick into the path of a Mack truck; for Bohr everyday reality exists, but not as the deterministic outcome of events at the quantum level. According to Bohr, the meaning of life is not to be found in quantum mechanics. To recapitulate his thesis, *there is no deep reality.* Bohr's nihilist position is sometimes referred to as the Strong Copenhagen Interpretation.

"The majority of physicists swear at least nominal allegiance to Bohr's anti-realist creed" (Herbert, 1985, p. 16). Even so, many of Bohr's followers prefer the version of the Copenhagen Interpretation that Heisenberg tended to favor, sometimes called the Weak Copenhagen Interpretation. This interpretation reads: *Reality is created through the process of observation.*

> Although the numerous physicists of the Copenhagen school do not believe in deep reality, they assert the existence of *phenomenal reality.* What we see is undoubtedly real, they say, but these phenomena are not really there in the absence of an observation. (Herbert, 1985, p. 17)

The physics of this interpretation has an ontological component. In the Weak Copenhagen Interpretation, reality comes into being when the "wave potential" or "wave function" is collapsed and material (i.e., particle) reality is realized. As Heisenberg asserted, the process of observation collapses that wave function and turns a potential reality into a fully realized one. One of the main criticisms of the Weak Copenhagen Interpretation (other than the standard critique by the naive realists) is that it is dealing with apples and oranges, not a discrete level or condition of reality. It treats the observer and the measuring instrument in Classical terms while treating the phenomenon under study in quantum terms. As Casti (1989, p. 444) points out, this is the same schizophrenia that Descartes infected the Newtonian paradigm with. There have been basically two ways out of this conundrum, neither being any more satisfactory to the naive realists.

John von Neumann, 1903-1957, offered an elegant mathematical solution to the dualistic reality of the Weak Copenhagen Interpretation, resulting in what is called the Consciousness Interpretation: *consciousness creates reality.*

> [The] Copenhagen position maintained that there was a definite separation between the measuring device and the quantum object being measured, and that the wave function collapse was assumed to occur in some vague neighborhood between the two. To everyone's surprise and consternation, when he put the object and the device on the same footing by thinking of them both as quantum objects, . . . [he] discovered that as far as the final observed results were concerned, he could put the "cut" between the two anywhere he pleased. . . . in the system, in the device, or anywhere in between. (Casti, 1989, p. 44)

This implied that there could be no "innate" properties of ordinary objects to be realized when the wave function collapsed. "In fact, by this result the world cannot even be constructed out of combinations of *unobservable* ordinary objects" (Casti, 1989, p. 444). Von Neumann concluded that such "attributes" were no more than the "real" products of human consciousness. In sum, *consciousness creates reality*. It is, for the most part, a reversion to philosophical idealism.[41] Of course, the persistent problem with von Neumann's interpretation, as with all idealist philosophy, is that it can't be *disproved*. The other escape from the dualism of the Weak Copenhagen Interpretation is the Austin Interpretation.

The Austin Interpretation also contends that reality is a product of the process of observation. This approach treats reality as the combination of all possible histories and futures, with the human act of observation (or *choice*) determining what becomes ontologically real.

> We should hasten to note that the Austin Interpretation champions an *observer*-created reality, not a consciousness-created one. The Austin view, while differing from the Copenhagen in significant ways, still accepts some of the crucial aspects of Bohr's position. Most important, the two schools agree

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[41] Philosophical idealism comes in a variety of forms. Berkeley's "metaphysical idealism" suggested that ideas originate through the process of conscious thought as opposed to originating in the external world. Kant's "transcendental idealism" pitted a world of "things-in-themselves," i.e., noumena, which eluded sensory experience against a phenomenal world of sensory experience which bound man to a two-dimensional existence (Kant, 1781/1934). Kant's great contribution was the conclusion that the noumenal world becomes the "real" world through the ideal and active reconstruction of everyday life (see Sahakian, 1968, pp. 172-172 for an excellent summary). Hegel's "absolute idealism" externalized Kant's marriage of intuition and reason into what Hegel called the *weltgeist*, or universal human spirit. Regardless of the variety, philosophical idealism challenges the classical contention that the "real" world exists independent of and/or external our conscious awareness of it. Of course, given that our consciousness is the only means of perception we have, it is impossible for consciousness to negate itself in order to prove the existence of anything "not consciousness" .... On the other hand, idealism can neither disprove the *possibility* of an external objective world.

> that scientists can communicate unambiguously only about the final results of a measurement. For Wheeler, the essence of existence (reality) is meaning, and the essence of meaning is communication defined as the joint product of all the evidence available to those who communicate. In this view meaning (i.e., reality) rests on action, which means decisions, which in turn force the choice between complementary questions and the distinguishing answers. Putting all these links together, out pops the Austin Interpretation of reality generation by exercise of the quantum measurement option. (Casti, 1989, p. 449)

Thus, in the Austin Interpretation, ontological reality is contingent upon a Habermas-like this-worldly social constructionism where meaning (i.e., reality) is determined by the questions we ask, the measurements we take, and the solutions we communicate. Interestingly, supporters of the Austin Interpretation contend that this need not involve human consciousness. As long as the results of the measurement are communicated, the wave function can be considered as collapsed.[42]

Heisenberg, in his later years, rejected the nihilist position of Bohr and the phenomenal orientation of the Weak Copenhagen Interpretation. Heisenberg wanted to delve deeper into the ontological implications of quantum mechanics. As he considered the alternative interpretations put forth by his colleagues, the persistent question was not how reality was made (this was still a sociological process according to Heisenberg), but out of what it was made. His eventual conclusion formed the Duplex Interpretation. Heisenberg's Duplex Interpretation contends that *ontological reality is comprised of two parts: Potential and Actuality*. Ontological

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[42] Obviously, the sociological question remains as to whether communication implies consciousness and vice-versa.

reality, according to Heisenberg, consists of both the objective outcomes of events and all the potential outcomes of events from the past through the future. Phenomenal reality—the reality of everyday life—consists of the actualization of a potential event outcome which occurs at the moment the process of observation and measurement collapses the probability wave function relating to that particular event. Keep in mind that there are no longer fundamental particles forming the glue of our world. The fundamental process at the base of the physical world[43] is a *tendency* or *potential* set of event outcomes in which the material world may or may not manifest itself. This results in two universes, so to be speak: one of potentiality and the other of actuality. In light of these considerations, Heisenberg's Duplex Interpretation offers a satisfactory ontological interpretation of reality. However, following the same logic as Heisenberg, another interpretation sounds more like science fiction than reasoned fact: Everett's Many-Worlds Interpretation.

The Many-Worlds Interpretation (in Herbert, 1985, p. 19; also Wolf, 1988) claims that *reality consists of a steadily increasing number of parallel universes*. The main appeal of the Many-Worlds Interpretation is that it overcomes the dualism of quantum measurement. It does this, however, by proposing that every potential outcome of every potential event creates an alternative universe regardless of whether any particular outcome was measured or not. This interpretation is, perhaps,

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[43] The question still remains whether this can be called a "deep reality" or not.

the hardest to swallow since it is the farthest removed from our everyday experiences. Less bizarre, but more often misinterpreted and misunderstood, is the Wholeness Interpretation.

The Wholeness Interpretation states that *ontological reality is an undivided wholeness which cannot be understood in terms of the structural properties of its constituent parts.* This is the position put forth by Fritjof Capra and the late David Bohm.[44] The key to understanding the Wholeness Interpretation is understanding *nonlocality*. John Bell first proposed the nonlocality assumption in what is now called Bell's Theorem.[45] Bell offered a mathematical proof that Einstein was wrong in his contentions that the quantum indeterminacy problem was the result of hidden variables operating at the local level. Bell concluded that, given the speed of light as a mathematical constant and physical limit, "local" realities cannot explain all quantum events. Nonlocality is rather difficult to conceptualize. Bohm gives the example of a universal domino effect in which the quantum world is like a huge row of dominoes. The twist is that the dominoes are all hooked together at the top of each piece such that the movement of one simultaneously results in the movement of all others. Capra's analogy is a web (think of a spiderweb) of interconnected processes where a disturbance or event in one area is immediately felt in all other

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[44] The wholeness theme runs throughout the voluminous works of both Bohm and Capra. See in particular Capra (1983; 1989; 1991), Capra & Steindl-Rast (1991), Bohm (1983), and Bohm & Hiley (1993).

[45] See Herbert (1985, pp. 211-231) for an excellent summary of Bell's Interconnectedness Theorem, its various nuances, implications, and critics.

areas. Regardless, the Wholeness Interpretation dismisses any discrete boundaries between objects and events, particularly between the observer and what is observed. Time itself is considered as an undivided whole in the Wholeness Interpretation, thus the concept of cause and effect becomes meaningless. The difficulty with the Wholeness Interpretation is its intangible abstract nature. How does one "know" this ontological reality—especially since a theory that explains everything in terms of everything else is no more valuable than no theory at all? Capra (1991, p. 287) contends that Science is limited as a way of knowing and understanding this vast multi-dimensional ontological reality. Thus, people socially construct a reality in which they are comfortable and can impose some sense of regularity on. These social constructions in the form of scientific theories are "necessary approximations" of ontological reality—and, as such, make Science (and human survival) possible (Capra, 1991, p. 287). Thus, the Wholeness Interpretation asserts that there is an ontological reality which transcends, yet includes, phenomenal reality. Bohm makes a similar statement in regard to the epistemological and ontological limits of Science.

> [Appearances are] what arise in our *perception* of the world. As we have seen, the appearances in sense perception give rise to inferences about an essence that might be their origin, but this essence, which is seen in thought, turns out to be yet another appearance and therefore still part of our overall perception. Our theories are not primarily forms of knowledge about the world but rather, they are forms of insight that arise in our attempts to obtain a perception of a deeper nature of reality as a whole.... In all this, scientific theory may even go so far as to throw some light on the observer, to whom all these appearances are supposed to be taking place. But as with everything else, even such theories are only further extensions of appearances, so to speak, which give the observer a mental mirror in which he or she is reflected. There will therefore be no final theory of the observer. The ultimate nature of

> awareness is unlimited and unknown, like that of the universe as a whole of which it is a part. (Bohm & Hiley, 1993, p. 324)

The Wholeness Interpretation rejects the assumption that local events collapse the wave function and create reality. In this approach, the question itself is immaterial. In a strictly non-deterministic sense, ontological reality was always there—the proper question is a sociological one: What role do we and our decisions play in how this "wholeness" unfolds? The Wholeness Interpretation is an elegant philosophical doctrine. Even so, such questions and interpretations offer little comfort for the pragmatic realists. The remaining interpretations of quantum theory[46] all share the assumption that ontological reality has real attributes completely independent of the observer and the process of measurement.

Of the proponents of the Realist interpretations of quantum theory, Einstein was the most famous and most vocal. Einstein remained a naive realist until the end. Along with the other realists (which includes most of the applied scientists who spend their time working on everyday problems), Einstein treated the objective material world as an *a priori* concept. Realists are confident that *something with real empirically-identifiable attributes is there whether one is looking at it or not* and that science can explain where it came from in addition to where its going, in accordance with the inherent laws[47] of nature. Most realists are content to limit themselves to

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[46] The list and discussion herein is intended to be somewhat representative, but by no means exhaustive, of all the different interpretations of quantum theory.

[47] In effect, Classical laws.

solutions of everyday problems that fall within the bounds of the Classical scientific paradigm. Quantum theory, to them, is only a tool to be used if the problem at hand falls outside of the bounds of Classical concepts. With the possible exception of Einstein, most realists are not bothered with epistemological and ontological questions about the nature of reality. Those that are take one of two popular neorealist stands in regard to the ontological implications of quantum theory: the Quantum Logic argument and the Hidden Variables argument.

The first neorealist position is that of Quantum Logic. The Quantum Logic Interpretation contends that *quantum reality is no more than a subset of reality in the Newtonian sense, except that it requires a language and logic which we don't yet have.* To these neorealists, quantum reality is a "deep reality" that we don't have the tools to understand yet. An analogy is often given that quantum physics needs to create a new language of understanding in the same manner that Newton created calculus to understand the universe, or Reimann created non-Euclidean geometry through which we can better understand relativity.

Of course, according to the proponents of the Realist Interpretation, what is needed to resolve this problem is more empirical science in the spirit of the true Classical paradigm. This is the basis of the alternative neorealist position: the Reactionary Interpretation. Assuming that the Classical model is correct, the reactionaries propose that ontological reality is exactly as Newton explained it; however, at the quantum level, it must have *hidden variables which cause the* *unanticipated effects in quantum experiments.* In spite of the neorealist faith in the Classical Newtonian model of a wholly objective and predictable universe, quantum theory remains the ghost in Newton's machine.

Any effort to integrate or summarize these several wide-ranging interpretations of quantum theory is difficult. What do these various interpretations of quantum theory have in common? What generalizations can be made in the quest for a better understanding of ontological reality? At first, one notices that the concept of ontological reality varies from interpretation to interpretation. In some cases, e.g., the Many-Worlds Interpretation, the Duplex Interpretation, and the Wholeness Interpretation, ontological reality encompasses events which are not only outside our epistemological frame of reference, but even outside the range of probability. In such an ontological framework, our knowledge (i.e., epistemology) will remain, by necessity, very small. In the other direction, other interpretations, e.g., the Weak Copenhagen Interpretation, equate ontological reality with phenomenal reality, or in the extreme cases with consciousness (the Consciousness Interpretation) or crass empiricism (the realist and neorealist positions). Some fail to adequately distinguish between ontology and epistemology (e.g., the Austin Interpretation). Many reject any ontological implications all together:

> Physicists do of course carry around with them a working philosophy. For most of us, it is a rough-and-ready realism, a belief in the objective reality of the ingredients of our scientific theories. But this has been learned through the experience of scientific research and rarely from the teachings of philosophers. . . . [We] should not expect [philosophy] to provide today's

> scientists with any useful guidance about how to go about their work or about what they are likely to find. (Weinberg, 1992, p. 167)

The most common feature of the various interpretations of quantum theory is that the place of the observer must be taken into consideration. Even though Bohm (1993) argues that, in his theory, the essence of nonlocality removes the observer from the high throne of reality creation, it still does not negate the impact of the observer on the system as a whole. The antithesis of the "role of the observer" thesis is offered explicitly by the naive realists who still assume the validity of the Cartesian dualism between mind and matter. However, it could be argued that the role of the observer in the neorealist interpretation is to *not* interfere with the phenomena under study.[48] Most scientists today agree that the possibility of objectively detached observation is an impossibility. Quantum physics has, for all practical purposes, destroyed the Cartesian separation of object and subject, mind and matter, observer and observed. In its place it has made an explicit call for sociological variables to help explain the process in which we actively participate in reality building . In doing so, it has also challenged the Newtonian assumption of structural determinism.

As Heisenberg (1949) pointed out, it is only in closed systems that we can make the assumption of complete determinacy. For all practical purposes, even at the "material" level of reality, closed systems seldom exist outside of the laboratory. Whether one accepts the existence of any deep reality or not, the random nature of

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[48] Whether this is possible or not is entirely another question. The sociological variable of observation is still a significant one in the interpretation.

event outcomes seriously challenges the assumption of discrete fundamental particles which obey innate natural laws. Such a revelation also opens another can of worms, i.e., if the universe is, at the most basic level, random, from where does order come? The search for fundamentals has, since the general recognition of quantum theory and its ontological implications, turned into a search for the nature of order. Though much more time could be devoted to the discussion of the essentials of quantum theory, the discussion must now turn to the question of order and disorder. Several derivatives of and spin-offs from quantum theory have tried to locate the nature of order in an otherwise indeterminate and probabilistic universe. Though the list is not all-inclusive, a least a few of these attempts warrant discussion.

The Search for Order

The death of determinism

Newton's world was a world of order and determinism. Newton firmly believed that the most useful tool in understanding the innate order of the universe—to determine cause and effect—was mathematics.

> The most perfect mathematical expression of determinism is the differential equation. It is the mathematical tool which was created by Newton to derive Kepler's laws from the gravitational pull. Even today, a deterministic system is a system which can be modeled by a differential equation. It has the fundamental property that its state at any time completely determines all subsequent (and preceding) states, and there are numerical procedures to compute the state at any time *t* from the initial state and the equation. (Ekeland, 1988, pp. 20-21)

Quantum theory rejected Newtonian determinism and replaced the linear mathematical modeling with nonlinear probability models. This was necessitated by two previously discussed theoretical shifts in the move from Classical to quantum thought. The first was the quantum measurement problem and Heisenberg's uncertainty principle, which confirmed the impossibility of any precise measurements of linear space-time relationships. The second theoretical shift was the move from structural antecedents to the primacy of process, e.g., in Planck's blackbody radiation studies Newtonian linearity broke down at certain points, resulting in the "blackbody catastrophe." The idea of indeterminate and/or catastrophic systems formed the basis for several branches of quantum theory, all having the common goal of trying to explain the nature of order.

Catastrophe theory

Catastrophe theory is a mathematical model which can be traced back to the blackbody radiation problem. This theory suggests that order is innate in the universe and can be modeled linearly using mathematics. Yet, at certain conjunctures of variables, linear systems sometimes take on a nonlinear form with unpredictable consequences. Several assumptions are made in catastrophe theory (see Ekeland, 1988, pp. 88-108). The primary defining assumption is that the system under observation is a closed system in a state of equilibrium. The parameters of the system can be defined in a quantum manner as "the totality of all its possible responses to the world outside" (Ekeland, 1988, p. 91). External variables (usually three for optimal modeling flexibility) with random values are then introduced into the system, which alter the system in a typical linear fashion. At some point, however, the equilibrium of the system dissipates, and the system may jump to a visibly different state of equilibrium. The mathematical model lends itself to graphical illustrations in which the data take regular shapes and forms, e.g., folds, cusps, swallowtails, elliptic umbilic, hyperbolic umbilic, butterfly, parabolic umbilic, etc. (Toulouse, 1981, pp. 101-103). An example of such a system in nature is the combination of one oxygen and two hydrogen atoms. As temperature variation is introduced, the internal state of the water varies linearly with the external temperature until the critical value of freezing, at one end, and boiling, at the other. Theoretically, the model suggests that even disorder in the universe takes on regular shapes and forms—in fact, Thom[49] suggested that all apparent order in the universe resulted from catastrophes in otherwise stable closed systems. However, in spite of its broad application and popularity during the 1970s, catastrophe theory has not experienced much success in explaining real-world phenomena.

> In the twenty years of its existence, there has not been a single undisputed success of catastrophe theory in the field of experimental science, that is, and undisputed fact that could be explained more adequately by catastrophe theory than by other means. (Ekeland, 1988, p. 103)

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[49] Rene Thom introduced catastrophe theory in his 1972/1975 book *Structural Stability and Morphogenesis: An Essay on the General Theory of Models.*

In the sense of taking order and stability *a priori*, catastrophe theory may fit better into a Newtonian framework and not in the Post-Newtonian or post-quantum theoretical categories. A close cousin of catastrophe theory is the theory of chaos.

Chaos theory

The theory of chaos started with Lorenz in 1960, but did not reach its zenith until the publication of James Gleick's (1987) book *Chaos: Making a New Science.* Like catastrophe theory, its link to quantum theory is the use of mathematical modeling to illustrate the nature of order in natural systems. Like quantum theory itself, chaos theory was born out of a search for the Classical regularities supposedly inherent in nature. As told by Gleick (1987), Edward Lorenz sought to model meteorological patterns using an early primitive computer (affectionately named the Royal McBee). Lorenz defined several variables and formulated a routine which could reasonably approximate normal weather patterns in its output. As the story goes, he sought to repeat a series of runs that he found interesting, so he entered in the variable values where the interesting pattern started and then went for coffee (the Royal McBee was not famous for its speedy calculations). Upon his return over an hour later, Lorenz was wholeheartedly disappointed to find that the output did not at all resemble what he had wanted. Something had gone wrong—possibly a failure of one of the mighty McBee's vacuum tubes. However, upon retracing his steps, he found that one of the variable values, .506127, had been rounded to .506 at the start of the new run. Lorenz was awestruck. Assuming, in the Classical deterministic sense, that random errors and events in a normal system inevitably cancel themselves out, Lorenz could not understand how such a different outcome could result from such a mathematically insignificant change in a single variable among so many others.

> If a weather satellite can read ocean-surface temperature to within one part in a thousand, its operators consider themselves lucky. Lorenz's Royal McBee was implementing the [C]lassical program. It used a purely deterministic system of equations. Given a particular starting point, the weather would unfold exactly the same way each time. Given a slightly different starting point, the weather should unfold in a slightly different way. A small numerical error was like a small puff of wind—surely the small puffs faded or canceled each other out before they could change important, large-scale features of the weather. Yet in Lorenz's particular system of equations, small errors proved catastrophic. (Gleick, 1987, pp. 16-17)

Lorenz did not know enough about digital computing to realize that computers perform this type of rounding all the time in the normal course of their operations. Given the fact that not all numbers are discrete, small deviations from the true values of variables are inevitable. In the Classical paradigm, errors occur in a random fashion and can be expected to cancel themselves out.[50] However, in mathematical models which use recursive calculations, small deviations and errors become multiplied exponentially at each recursion. Similarly, any linear equation in which variables are combined to form exponential values, small errors and deviations can quickly become large ones. The idea that any small perturbation in a normal linear

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[50] Note that this applies to closed systems only—the type that Newton saw as the structural framework of the universe. Quantum mechanics recognizes that most systems are in fact open systems where perturbations and new variables occur in ways which will definitely not "average out" over time or produce the same anticipated results.

system can produce catastrophic results is called the *Butterfly Effect*. This term came from Lorenz's findings that something as apparently insignificant as the flapping of a butterfly's wings can significantly affect the weather, even on the other side of the world. Lorenz did not stop there, for he then sought to extend his findings to nonlinear systems—systems in which the variables did not have specific relationships over time. He began modeling nonlinear number systems on the computer, i.e., recursively plotting three random variables as a point in space on a three dimensional coordinate system. Common sense tells us there should be no recognizable pattern. Lorenz's results did not complement common sense.

> [T]he map displayed a kind of infinite complexity. It always stayed within certain bounds, never running off the page but never repeating itself, either. It traced a strange, distinctive shape, a kind of double spiral in three dimensions, like a butterfly with its two wings. The shape signaled pure disorder, since no point or pattern of points ever recurred. Yet it also signaled a new kind of order. . . . [It said] "this is complicated." All the richness of chaos was there. (Gleick, 1987, pp. 30-31)

This type of mathematical modeling became quite popular, particularly after Benoit Mandelbrot devised a set of computer algorithms which resulted in aesthetically stunning and complex pictures. Mandelbrot advanced chaos theory another step with models that produced the same complex patterns at multiple degrees of magnification. Call it "random order" or "ordered randomness," but chaos theory suggests that random events can take on complex and apparently orderly behaviors. Chaos theory, like catastrophe theory, tried to restore a Newtonian faith in the regularity of the world—even random events (i.e., at the micro and/or quantum level) can evolve into regular orderly systems. The primary distinction between catastrophe theory and chaos theory is that catastrophe theory assumes an initial and innate state of order while chaos theory need not make that assumption. Another difference is that catastrophe theory relies primarily on mathematical equations while chaos theory utilizes visual models and places less emphasis on mathematical equations. In spite of this aesthetic appeal, chaos theory can be criticized on several counts. First, chaos theory ignores the epistemological foundation of its own success, i.e., humans *perceive* complex patterns in randomly constructed pictures. Is this "order" inherent in the model or a result of the human attribution process, i.e., a gloried Rorschach test? Chaos theory fails to take into account the place and role of the observer. Second, especially in the Mandelbrot sets, is this apparent order simply a result of recursive mathematical structures built in to the equations that produce the fractal images? If so, such results, though aesthetically awesome, are not unexpected. Third, given the fact that computers cannot generate true random numbers in a recursive fashion, are the models simply reflecting some innate "order," i.e., random limit, in digital information processing? The most serious critique of chaos theory is that it fails to answer the question which spurred its own development: Where does order come from? In response to this question, the science of complexity picks up where the science of chaos left off.

The science of complexity

Of all its supporters, Ilya Prigogine (1980) has probably offered the best outline of the basic tenets of complexity theory (also see Glansdorff & Prigogine, 1981; Prigogine & Stengers, 1984; Nicolis & Prigogine, 1989). Prigogine is especially interested in time, change, and the process of entropy. Einstein had originally proposed that time was a human construct and could, at least in theory, be reversible. Prigogine, in his search for order, wanted to identify those things in the material world which could not be reversed, even if time itself could—this could be the key to how order unfolds in the universe. Drawing from the existing tenets of catastrophe and chaos theories, Prigogine's goal was nothing less than showing how random, yet irreversible, fluctuations in the microscopic environment lead to enduring structural consistencies in the macro-environment which, in turn, have reciprocal effects on the microscopic environment. This is possible because time and entropy have different implications in open systems than in closed systems. In closed systems, entropy is well defined—the possible options for the system inevitably and progressively decrease over time as the system evolves. In closed systems, the second law of thermodynamics actually supersedes the first, i.e., system equilibrium is achieved at a zero-state of energy transfer. Most systems, however, are open systems and can exchange energy with other systems in the environment—here the first law of thermodynamics can supersede the second and equilibrium can be maintained at high energy transfer levels.[51] Given that the continuity of any system depends on its ability to postpone its own entropic demise, order in the natural world arises when the mutual energy exchange between systems and/or subsystems optimizes this energy exchange function. Such systems are referred to as *self-generating systems*, since they are able to regenerate (at least most) their energy lost to entropy through exchange with other systems. For self-generating systems, entropy is not so much a dissipation of energy, but a progressive reduction in possible event outcomes for the system itself. Ironically, the reduction of possible event outcomes also gives the appearance of an increase in order, since, for irreversible processes, fewer possible outcomes translate into a higher probability of the occurrence of any single outcome. Complexity theory sees this as an ongoing process of change (i.e., *becoming*), and invokes the inevitability of catastrophe as well as the emergence of recursive random patterns like those illustrated by chaos theory. Complexity theory shows great promise in uniting the macro and micro levels of reality in an understandable way. It has also achieved some success in modeling social phenomena, e.g., economics, population dynamics (see Waldrop, 1992). With Prigogine and his science of complexity, the Newtonian paradigm can be formally declared dead in the natural sciences.

> Both at the macroscopic and microscopic levels, the natural sciences have thus rid themselves of a conception of objective reality that implied that novelty and diversity had to be denied in the name of immutable universal laws. They have rid themselves of a fascination with a rationality taken as closed and a knowledge seen as nearly achieved. They are now open to the unexpected,

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[51] This does not negate the second law of thermodynamics, it just shifts the entropy function to a different part of the larger system.

> which they no longer define as the result of imperfect knowledge or insufficient control. (Prigogine & Stengers, 1984, p. 306)

In contrast with mankind's position in Aristotle's or even Descartes' world, we are now fairly comfortable with our place on the edge of a universe hanging precariously between order and chaos. The idea of detached observation, linear causality, and innate natural laws exists only in a parallel universe where humankind did not happen to evolve the way they did. We are not passive observers, but active creators of the universe we seek to understand. As a product of nature that has come to realize itself,[52] we have also inherited our own destinies. The quest for order in Post-Newtonian science has come full circle and dumped the problem back in our laps.

> We can no longer accept the old a priori distinction between scientific and ethical values. This was possible at a time when the external world and our internal world appeared to conflict, to be nearly orthogonal. Today we know that time [and science itself] is a [social] construction and therefore carries an ethical responsibility. (Prigogine & Stengers, 1984, p. 312)

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[52] The idea of nature realizing itself transcends the Classical dualism of mind and matter, putting another tenet of the Newtonian worldview to rest. It also changes humankind's position in the universe—previously, man was thought to have been the center of the universe and "above" nature itself. Knowing the mechanics of quantum theory and self-generating systems, we can now understand how humans evolved along with other natural systems and subsystems. However, the result (as opposed to cause) is that this natural process of evolution has acquired the ability to realize itself. The Wholeness Interpretation of quantum theory addresses this directly and relocates humankind not in the center of the geographic universe, but in the center of a universal responsibility to create and recreate the most viable world vis-à-vis the entropic process. As Prigogine points out (1984), our origin and success as a species is due to thwarting our own entropic demise by borrowing resources from other natural systems. The larger problem, according to Capra and the Wholeness Interpretation of quantum mechanics (1983, pp. 15-18), is in the fragmented, dominating, deterministic assumptions of the Classical Newtonian paradigm. What is needed is a "new paradigm" and a "fundamental change in our thoughts, perceptions, and values. . . . we need an ecological perspective which the Cartesian world view does not offer" (Capra, 1983, p. 16).

Thus, according to the physicists, in an unpredictable world where every decision we make closes future opportunities (i.e., the entropy function for open systems) the last remaining variables are, by necessity, sociological. How are the social sciences addressing these issues? Has there been a comparable scientific revolution in the social sciences as there has been in the natural sciences?

POST-NEWTONIAN FOUNDATIONS FOR A NEW SOCIAL SCIENCE

Paradigms Revisited

Before examining the paradigmatic state of the social sciences, a few qualifications are in order. First, one cannot assume that a great deal of consensus exists in the natural sciences in regard to the shift from the Classical Newtonian worldview to a Post-Newtonian worldview. By far, the majority of practicing scientists in the natural sciences are not concerned with natural philosophy, ontology, nor epistemology. The state of Science[53] in the Western world might be compared to the science of the Ancient Roman world: The question is not "what is?" but "what is the use?". Thus, the case for a narrower definition of paradigm could be made when considering science as simply a modern way of knowing. Disciplines are fragmented and knowledge itself is disseminated in a highly stratified manner and form. Scholarly journals within disciplines have policies as to what constitutes "knowledge" in their field and what falls outside of that definition. Similarly, the use of mathematical and statistical modeling takes on specific forms within specific disciplines, and noticeably different forms in different areas. Seldom does one find the philosophy department located anywhere near the physics laboratories. At the same time, most school children and college freshmen are still taught science and

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[53] Recall the previous distinction made between Science and science.

physics from the Classical perspective.[54] In sum, one cannot assume that there has been, or will be, a widespread move in the natural sciences toward a Post-Newtonian worldview. This is not to say that such a shift is not taking place. Just as people at one time were afraid they would fall off a spherical world, people also fear the responsibility implied by a non-deterministic world where man is a product of nature as well as a progenitor of nature itself. To reiterate a statement by Kuhn, such paradigmatic revolutions require "the reconstruction of prior theory and the re-evaluation of prior fact, an intrinsically revolutionary process that is seldom completed by a single man and never overnight" (Kuhn, 1970, p. 7).

A second issue must also be addressed. In spite of August Comte's popularization of the concepts of positivism, one cannot assume that the social sciences, and sociology in particular, are completely organized around Classical Newtonian principles and perspectives. The reason is that the social sciences have always been home to strong anti-positivist factions. Sociology, in particular, has several theoretical divisions, ranging from hermeneutical to humanistic, which explicitly critique positivism and scientism in general, even to the point of openly rejecting the basic tenets of positivism altogether. However, to reiterate the analysis of Halfpenny,

> What is of interest here is not whether positivism of some sort is able to disarm or absorb [its critics], but that the challengers take positivism, as their

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[54] Of course, we're still waiting for an alternative to the Classical perspective as it applies to the social sciences.

> target, still assuming that it is the dominant form of sociology to be discredited and transcended by their preferred alternatives. (1982, p. 120)

Thus, in spite of the fact that the Classical worldview and method is not without critics, by most accounts, it forms the dominant worldview of the social sciences and sociology.

The goal herein is not to resolve the debate, nor to extol the merits and pitfalls of any particular perspective. However, it can be demonstrated that many of the perceived "crises" in the social sciences derive from similar crises in the natural sciences, resulting directly from the historical influence of the natural sciences on the social sciences. What is interesting is that, in the natural sciences, many of these obstacles are being overcome in the paradigmatic shift from the Newtonian to a Post-Newtonian worldview, while the social sciences are still awaiting a resolution to their crises. Finally, of interest herein, is the fact that the Post-Newtonian worldview emphasizes *sociological* variables and principles in its ontological and epistemological foundations. What conclusions can be arrived at in regard to crises and paradigm shifts in the natural and social sciences? Can a complementary and/or encompassing worldview be constructed? Can the social sciences meet the quantum call for sociological variables?

Old Paradigm Crises in the Social Sciences

The first and foremost crisis in the social sciences is the nature of order. Most all questions in the social sciences can be either directly or indirectly traced back to this initial conceptual problem. The origin and nature of order has, since the dawn of history, been attributed to the clockwork-like machinery of nature.[55] In the Classical paradigm it was believed that the machinery of nature could be best understood by understanding the structure and functions of each constituent part. Few historians of science or society would disagree with the notion that the machine paradigm has dominated our understanding of the world since the time of Newton, if not before. As Toffler contends,

> Nevertheless, despite all the ifs, ands, and buts, it remains fair to say, as Prigogine and Stengers do, that the machine paradigm is still the "reference point" for physics and the core model of science in general. Indeed, so powerful is its continuing influence that much of social science, and especially economics, remains under its spell. (Toffler, in Prigogine & Stengers, 1984, p. xiv.)

Early sociologists, psychologists, political scientists, economists, and other social scientists developed "real," discrete, and deterministic structures and forms within their respective disciplines. This was especially true in sociology.

> Although critics have focused on the distant influence of Aristotle or the authority of organic metaphors in the romantic and Darwinian nineteenth century, the underlying premise for the practice of treating "society" or "history" as a unitary organism was the belief in deterministic natural laws [i.e.,

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[55] The importance of a clock-keeper (i.e., God or gods) has fallen in and out of our collective worldviews throughout history, while the notion that "order" is inherent in the universe has remained, for the most part, in tact.

> the machine model]. Just as the "economy" had tended to be a closed system of variables from whose action all change in the system could be deduced, so too did society. Once the chief dynamic factors had been specified, rooted in nature, and the trajectory of their action set, history developed by an inner logic along a precharted course, substantially immune to the contingencies of historical change. (Ross, 1991, p. 18)

Thus, as the social sciences developed around the machine model, they quite naturally took structure *a priori* and treated process as a "function" of structure itself. Order and structure were treated as synonymous concepts as opposed to discrete emergent ones. In sociology, Comte based his "social physics" on the assumption that society is a separate structure and level of reality vis-á-vis the individuals that comprise it. Durkheim carried Comte's assumption to its logical extreme and concluded that society existed *sui generis*, inevitably determining the properties of its constituent members. Durkheim's attempt (1897/1951) to [re]establish this link between society and individuals in his study of suicide illustrates too well how social structures came to be taken *a priori* and process variables treated as functions or effects of these structures. The result was a pronounced gap between the macro-level reality of "invisible determining structures" and the micro-level reality of everyday people, personalities, and lives. This led to several other crises in the social sciences.

The ideas of Hobbes and Descartes combined to give us a fragmented self to complement our fragmented external reality. The mind-body problem still plagues the social sciences and philosophy. Hobbes and Freud both located order external to individuals. Descartes divided reality into discrete objective and subjective realms.

Newtonian science declared the subjective realm as antithetical to the new scientific method. Thus, by necessity, the observer had to be separated and removed from the object of observation. The result was that the social sciences, like the natural sciences, ignored most of the "ways of knowing" that contribute to the very essence of social reality, i.e., tradition, aesthetics and culture, authority, faith, intuition, etc. In spite of the explicit humanism of prophets like Saint-Simon and Marx , the positivism and scientism of progress negated the "social" dimension of man they sought to understand and control.

> The Copernican revolution had dislodged man from the center of the universe; it remained for the Galilean-Newtonian revolution to remove him from the universe altogether. Through the inexorable reduction of all knowable reality to the dimensions of objective mechanism, the gap between the knower and the known, between the subjective self and the world, came to be the measure of the distance between appearance and reality. Only the *primary* qualities (number, figure, magnitude, position and motion), inhering in the object "out there," were henceforth to be regarded as substantially real; the *secondary qualities* (all else which the sense perceive or the mind assembles), inhering in the human subject, were in effect unreal. (Matson, 1966, p. 4)

The result was an objective-subjective gap in the social sciences. This gap also extended to social science methodology, creating a crisis in the form of animosities between those making use of quantitative descriptive measures versus those relying primarily on qualitative ones. Quantum science now informs us that the observer, the observation, the mechanism of observation, the object, and the conclusion all form part of the reality under study and cannot be understood apart from each other. By ignoring epistemology and following the machine model of a detached independent external reality, the social sciences have lost the ability to detect how and why we construct the world as we do—ithat is to say, the parameters and essence of our very humanness. The result is a crisis of reductionism in the social sciences. Following the Classical model, once structures and objects can be isolated it is then possible to make cause-effect determinations. Aside from the arguments surrounding the human capacity for free will, the machine model of the social sciences seeks to reduce all phenomena to cause-and-effect relationships.

Taking social structure *a priori* raises a number of crucial questions and problems. The first is that cause-effect determinations, taken to their logical extreme, become an exercise in teleology.[56] Assuming that natural laws determine structural and behavioral outcomes, what else can be concluded except that social events either support (i.e., provide order) or don't support (introduce disorder) into the progressive evolution of society? What constitutes a discrete social structure? Can structures be understood by reduction to their fundamental parts, i.e., substructures? How do we know a social structure when we see one? By what mechanism does it impose itself on us? How are these structures maintained and reproduced, or, even more fundamentally, how did we get here from there? If we can't see them—or if we can only perceive them indirectly—how do we study them? By ignoring epistemological variables and taking social structure *a priori*, these questions remain major obstacles

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[56] Of course, an alternative to strict causal relationships is the comparative-historical method proposed by Weber (1903-1917/1949) in which only "necessary" causes are examined.

in the machine model of the social sciences—much like the "invisible particles," forms, and "substances" that make up the parts of Newton's grand universe. Yet the natural scientists are now calling for sociological variables in their understanding of the universe, specifically variables of *process*. Given the pervasive crises which now characterize the social sciences, how can the social sciences possibly hope to meet this call?

The Quantum Call for Sociological Variables

Before the social sciences can consider the quantum call for sociological variables in understanding how the world is created, ordered, and perceived, a summary of the shift from the Classical scientific paradigm to the Post-Newtonian worldview is in order. The best account of this shift is given by Fritjof Capra (1991) in *The Tao of Physics*. Capra openly subscribes to the "wholeness" interpretation of quantum reality, however, his summary can also be applied to the general understanding of quantum physics without excessive distortion.[57]

The first and most obvious shift involves the abandonment of the machine model as an explanatory concept. Explanation in the Classical paradigm involved

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[57] Capra's account has been sharply criticized by the naive realists; not because of factual inaccuracies but because of his detailed analogies between the new Post-Newtonian paradigm and the tenets of Eastern philosophy and mysticism. Note, however, that this similarity is recognized by other physicists, in particular, Paul Davies (1983).

isolating specific structures and then reducing those structures down to their constituent parts.

> Once you knew the parts—their fundamental properties and the mechanisms [i.e., functions] through which they interact—you could derive, at least in principle, the dynamics of the whole. Therefore the rule was: in order to understand any complex system, you break it up into its pieces. The pieces themselves cannot be explained nay further, expect by splitting them into smaller pieces. But as far as you want to go in this procedure, you will always end up, at some stage, with fundamental building blocks: elements, substances, particles, and so on—with properties you can no longer explain. From these fundamental building blocks with their fundamental laws of interaction you would then build up the larger whole and try to explain its dynamics if terms of the properties of the parts. This started with Democritus in ancient Greece; it was the procedure formalized by Descartes and Newton, and it has been the accepted scientific view until the twentieth century. (Capra, 1991, p. 328)

Now, with the quantum paradigm, we find that the "fundamental" particles, structures, and building blocks of material reality are not material at all. They are potentials—statistical possibilities in which structure (i.e., recurrent patterns) may or may not emerge. Thus, the laws of nature are not innate in the material manifestations of everyday life. Quantum physics offers us a fundamentally different view of the relationship between the parts and the whole. In the Post-Newtonian paradigm, the parts and whole cannot be reduced to a linear cause-and-effect relationship. According to Capra, "Whatever we call a part is merely a pattern that has some stability and therefore captures our attention" (1991, p. 329). Thus, the fundamental "nature" of reality is neither structural nor deterministic. Patterns, however, do exist. This leads to Capra's second criterion of new-paradigm thinking.

Since the time of Aristotle, the primacy of structure has been at the foundation of our science. Capra explains that

> In the old paradigm is was thought that there were fundamental structures, and then there were forces and mechanisms through which these interacted, which [eventually] gave rise to processes. (1991, p. 329)

For example, in the Classical Newtonian world, mass was considered to have the innate properties of attraction and repulsion (i.e., gravity and magnetism), which *caused* matter to move and organize itself in specific ways. All "objective" reality had mass and, thus, was required to obey the laws of gravity and motion. In the Post-Newtonian world, it was realized that mass is really a form of energy, gravity is a function of warped time-space, and attraction and repulsion are properties of inanimate fields, not particles. The Post-Newtonian paradigm shifts the focus from the primacy of material structures to the primacy of processes.

> This process thinking came into physics with Einstein's relativity theory. The recognition that mass is a form of energy eliminated the concept of material substance from science and with it also that of a fundamental structure. Subatomic particles are not made of any material stuff; they are patterns of energy. Energy, however, is associated with activity, with processes, and this implies that the nature of subatomic particles is intrinsically dynamic. When we observe them, we never see any substance, nor any fundamental structure. What we observe are dynamic patterns continually changing into one another—a continuous dance of energy. (Capra, 1991, p. 329)

The major criticism of Capra is to be found here, for one scientist put it, "He [Capra] thinks we're all electrons." Capra's goal here, however, is not to explain the pragmatic aspects of matter and motion, but to describe the ontological implications of the quantum paradigm. This is particularly significant for the social sciences, since the ontological assumptions of the social sciences were initially founded upon the assumption that structure precedes process and determines functions. Ontologically, the Post-Newtonian paradigm turns social science on its head. It implies that process, i.e., *action*, makes structure possible—it implies that human actors are, to at least some degree, the active creators of objective reality. Keep in mind that the "wholeness" interpretation implied by Capra (*ibid.*) is not as strong as many others in the call for sociological variables; some interpretations favor an objective reality created exclusively through the process of observation. In either case, the Classical deterministic primacy of structure must give way to the primacy of process, action, and potentiality.

> The image of the universe as a machine has been replaced by that of an interconnected, dynamic whole whose parts are essentially interdependent and have to be understood as [recurrent] patterns of a cosmic process [in which we play an active part]. In order to define an object in this interconnected web of relationships, we [as observers] cut through some of the interconnections—conceptually, as well as physically with our instruments of observation—and in doing so we isolate certain patterns and *interpret* them as objects. Different observers may do so in different ways.... What you see depends on how you look at it. (Capra, 1991, p. 330; italics added)

This brings us to Capra's third criterion for new-paradigm thinking in science: the shift from objective science to what he calls *epistemic* science. The necessity of epistemology in science derives from Heisenberg's uncertainty relations and operates on two different levels. First, given that our empirical sensory experiences are limited to the three primary dimensions, there are limits to the accuracy as well as the extent of our understanding. We cannot directly observe or experience phenomena above or below the threshold of our own perceptions; this includes "social" phenomena as well as physical phenomena of the very small and very large. All we can do is utilize other ways of knowing, i.e., logical-rational, intuition, historical-traditional, etc., in inferring the nature of those phenomena given their apparent effects. The second dimension of epistemic science arises from the conclusion that the observer is a critical component of the phenomena under study. As Capra points out,

> In the old paradigm, scientific descriptions were believed to be objective, that is, independent of the human observer and the [interpretive] process of knowledge. In the new paradigm, we believe that epistemology—the understanding of the process of knowledge—has to be included explicitly in the description of natural phenomena. At this point, there is no consensus among scientists about what is the proper epistemology, but there is an emerging consensus that epistemology will have to be an integral part of everyday scientific theory. (1991, p. 330)

It has already been demonstrated that the epistemology of science has changed over the course of history. At various times, Science has focused on various ways of knowing, including aesthetics, authority, empiricism, intuition, and logic. An epistemic approach to the new paradigm would recognize that all ways of knowing potentially form part of (a) the observer, (b) observation, and (c) that which is being observed. This is especially true for the social sciences. The Classical paradigm relied on crass empiricism as the ultimate measure of objective reality. Most of the the objects of Post-Newtonian science fall outside of the limits of our senses, so we must rely on ways of knowing other than strict empiricism. Given that the observer cannot be separated from the observation or object, we must also conclude that ontological reality encompasses all possible alternative ways of knowing and forms of knowledge. Within this ontological reality, normal science remains a social construction by which we collectively define what is objective and what falls outside of our definitions. Thus, if Science wants to make the shift from describing objective reality to the search for the meaning of ontological reality, an epistemic Science is clearly demanded.

The next shift is one from Classical descriptions of linear cause-and-effect descriptions to spatial descriptions of networks, interrelationships, and interconnected processes. Bohr used the term "complementarity" to replace the Newtonian notion of cause-and-effect.

> Bohr regarded the concept of complementarity as a generalization of causality appropriate to the mechanical description of objects whose behavior in principle cannot be separated from the measurement interactions that reveal this behavior. He saw the deterministic description of classical mechanics as intimately related to the classical notion of an object, characterized by a set of properties [i.e., structure] attributed to the object at each instant of time, quite independently of the physical systems required to observe these properties. . . . The quantities, or sets of quantities, associated with complementary phenomena can only be statistically related, since their mutual definition requires physical conditions which are not simultaneously applicable. The indeterminacy relations therefore express a reciprocal limitation on the extent to which complementary quantities may be defined simultaneously, and hence a limitation on the possibility of a causal description of events. (Bub, 1981, p. 139)

Complementarity means that complex interrelationships cannot be defined in terms of linear cause-and-effect. As Capra explains,

> Things exist by virtue of their mutually consistent relationships [i.e., complementarity], and all of physics has to follow uniquely from the

> requirement that its components be consistent with one another and with themselves. (1991, p. 332)

Statistically, complementarity implies that reciprocally related variables should not be isolated and used in linear models for the purposes of explanation or prediction. The Post-Newtonian paradigm contends that few, if any, causal-linear models are appropriate—real world phenomena are reciprocally related through a web of interconnected multidimensional interrelationships. No event outcomes are entirely predictable. However, by examining the potential outcomes of any event, the probability of any single outcome could be determined if enough information were available.[58] This turns the idea of scientific progress, as defined in the Classical paradigm, on its head. It implies that the only variables we can really manipulate are *sociological* ones—and even then the outcomes are unpredictable, or "fuzzy" at best.[59] This leads to Capra's fifth criterion for new-paradigm thinking: the relativity of science itself.

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[58] Note that this applies to well-defined closed systems only; there is no way to determine all possible variables in open systems, let alone all possible event outcomes.

[59] The question must be raised as to the tautological implications of such a statement. If natural open systems evolve in a random manner, and human intervention—in the form of nature realizing itself—exists as one of the few variables influencing the outcome of these otherwise random events, isn't the process *by definition* sociological? Many of the physicists examined herein contend that what is important is not the logical implications but the *ethical* implications of the role of the observer in constructing reality. Clearly, the idea that nature operates according to some deterministic formula or plan has to be abandoned. Though more often misinterpreted than not, the new theories deriving from Post-Newtonian assumptions (e.g., complexity, implicate order, wholeness) do NOT take order *a priori*. The defining characteristic of Post-Newtonian thought is that order is an emergent process, ultimately grounded in probability as opposed to "natural laws," and influenced greatly by the active awareness participation of the human species. Science is still possible, but science must also realize that it is a human creation which must ultimately understand itself before it can provide a window to the ontological world. Again, we are left with human sociological varaibles.

The Post-Newtonian paradigm suggests that the observer plays a critical part in the process and outcome of observation. Concomitantly, the observer plays an active creative role in the generation of the reality under observation. As Prigogine has already pointed out, Post-Newtonian science has shifted from an emphasis on "being" to the realization of "becoming" (1980). This always makes reality and our knowledge of it tentative and relative to the place and orientation of the observer.

> The Cartesian [Newtonian] paradigm was based on a belief in the certainty of scientific knowledge, which had been clearly stated by Descartes. In the new paradigm it is recognized that all scientific concepts and theories are limited and approximate. Science can never provide any complete and definitive understanding. Scientists do not deal with truth . . .they deal with limited and approximate descriptions of [phenomenal] reality. (Capra, 1991, p. 333)

The strength of science as a way of knowing is not found in its ability to distinguish fact from fiction. In this area, science is no better than other ways of knowing. Yet as any naive realist will tell, the strength of science as a way of knowing is found in its *sociological* dimension, i.e., the *collective* definition, pursuit, observation, explanation, and verification of worldly phenomena. Science is not synonymous with truth or with ontological understanding. Scientific descriptions are sociological approximations of the world which reflect the position[60] of those who observe it. In addition, the only variables within our immediate grasp are sociological ones; otherwise—in spite of how uncomfortable it makes us feel—all that remains is a throw of the dice.

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[60] "Position" in the geographic as well as epistemological sense.

Thus, the Post-Newtonian call for sociological variables is becoming clear. What would a social science based upon Post-Newtonian premises look like? What does this imply for the conduct of science within the social science disciplines? Can the social sciences meet the Post-Newtonian call for a sociological understanding of ontological reality? These are the critical questions to keep in mind as we proceed.

A NEW PARADIGM MODEL FOR THE SOCIAL SCIENCES

The social sciences have inherited many of their *a priori* assumptions about the world from the Classical scientific paradigm. The first is the notion of nature as a vast machine which must be understood in terms of the structures and functions of its fundamental parts. The social sciences, ironically, placed man outside of this vast machine. Theories of society (e.g., Comte, Durkheim) postulated real structures and changeless forms which existed independent of the actions of the people that comprised them—in spite of the fact that these people and their actions were "determined" by these structures. Theories of the individual (e.g., Hobbes, Spencer) also removed the individual from society, but saw determinism operating in the other direction—from hedonistic individuals. Order was located in the structure of society. Through detached analytic reductionism, one could determine the laws of society as well as the laws of nature.

> In the course of the nineteenth century the systematic projection into the "humane studies" of the spirit and method of Newtonian physics was carried to its extreme in nearly every direction. The two fundamental postulates of the scientific mechanist—those of neutral objectivity and analytic reductionism—came to be reflected, with varying degrees of accuracy and distortion in many of the most influential social theories of the period. (Matson, 1966, p. 15)

Recall Capra's statement that "Whatever we call a part is merely a pattern that has some stability and therefore captures our attention" (1991, p. 329), and that these patterns are really *processes* , *actions*, or *potentials*, which logically precede structure and make structure possible. In a Post-Newtonian model for the social sciences neither society nor the individual can be awarded primacy over the other. It is a dialectical and reciprocal relationship, one of Bohr's *complementarity* in which no linear cause-and-effect can be attributed. The social sciences can then be transformed and redefined as *the study of recurrent patterns of human actions and action potentials.* There still exists a macro-objective world of human and natural artifacts as well as a micro-subjective world of individual-level phenomena. Nonetheless, the first criteria for a Post-Newtonian model for the social sciences is that it must focus on the primacy of *process* above macro and micro level structures or functions.

Following the lead of Capra's new-paradigm thinking, a Post-Newtonian model for the social sciences must have a firm epistemological base. Knowledge cannot be viewed as a structure located either within or outside individuals. Knowledge and knowledge acquisition must be seen as a process through which we actively (individually as well as collectively) construct objective as well as ontological reality. This knowledge cannot be exclusionary like the knowledge inherent in the Classical paradigm. As active creators of ontological reality, our worldviews are comprised of all different ways of knowing (refer back to Table 1). Thus, a Post-Newtonian paradigm for the social recognizes that it is the variety of all ways of knowing which gives us our humanness. Science can still be defined in terms of the utilization of logic as a primary way of knowing, but this cannot be to the exclusion of all other ways. Our faith, values, emotions, etc., are part of us, and we are irreducibly part of the reality we wish to study. Thus, criterion two of a Post-Newtonian model for the social sciences is that knowledge must be seen as the process by which we individually and collectively construct ontological reality, and by definition must include all ways of knowing. This is an open rejection of the Classical Cartesian separation of mind, body, matter, and reality in general. Epistemologically, this means that knowledge is not an innate (or an ideal) structure, or a state of being, but a *process* of becoming. As such, it is relative, not quantifiable, *enabling*, and should not be treated as a commodity or tool of power and authority. It is the means by which we actively construct and reconstruct a viable world. Exclusionary tactics in regard to the knowledge process defeat the enabling epistemological and ontological purposes of the knowledge process itself.

The third criterion for a Post-Newtonian model for the social sciences is the rejection of linear cause-and-effect models. For the most part, the objects studied by the social sciences are parts of open systems. Statistical probabilities of event outcomes are usually not calculable in open systems since all variables cannot be known or controlled for. Even in closed systems, most real world phenomena are reciprocally related through a web of interconnected multidimensional relationships where assumptions about time order and causal relationships cannot be logically assumed. This is not to say that social phenomena cannot be modeled using mathematics, however, the search for the "natural laws" of human organization must be abandoned. In turn, that energy might be redirected into the search for ways in which we can reduce *social entropy*: the progressive reduction in available options for our continued survival.[61] According to the quantum physicists, these are the only variables which we can manipulate in which the outcomes are not entirely up to chance. This leads us to the fourth criterion for a Post-Newtonian social science.

Last, but not least, a Post-Newtonian social science must answer the quantum call for sociological variables. It must identify and address the role of the observer in the active creation of ontological reality. This is perhaps the hardest task at hand. It will undoubtedly take all our knowledge and all our ways of knowing to accomplish it. Yet this is the task at hand. Figure 1 is a graphical depiction of a Post-Newtonian "process" model for the social sciences.

The first thing to notice about this process model is that no linear cause-and-effect relationships are specified. There are no specific structures—only the **process** by which we collectively construct (i.e., objectification) and, in turn, collectively

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[61] The Classical Newtonian description of entropy was an extension of the second law of thermodynamics (i.e., energy moves from a state of high concentration to a state of lower concentration) and depicted the universe and all its parts as moving in a predetermined manner from a state of material order to a state of complete disorder (i.e., thermal equilibrium). Entropy in the Post-Newtonian sense does not assume any *a priori* state of order or disorder (see Prigogine & Stengers, 1984). In the Post-Newtonian explanation, entropy refers to the potential outcomes a set of interconnected events over time. Entropy in this sense refers to the progressive reduction in the number of possible end-states in a system as initial outcomes are realized and alternatives are reduced. Simultaneously, as potential outcomes are reduced, the probability of individual outcomes—relative to the total number of potential outcomes—increases. In terms of social entropy, this implies that every decision we make closes off an (as yet) unknown number of potential event outcomes in our future. The historical implication of social entropy is seen in the relative success of the humn species—we have eliminated or conquered many of the obstacles in our path, but at what cost? The future implications—given the human ability (even desire?) to destroy itself—place a grave responsibility in the hands of humankind to optimize diversity, adaptability, and viability in the face of an unpredictable and unknowable future. Such a future is unlikely to be realized on the basis of Classical concepts and methods.

experience (i.e., subjectification) the world in which we live. In this model, "objective" reality is a collective social construction where epistemology forms the key to understanding. Therefore, structure is not taken *a priori* but is a result of an ongoing process between collective action and common experiences. The assumptions and main tenets of the model are as follows. First, people share common experiences of the external world.[62] These experiences are then subjectified (i.e., abstracted) by each individual as symbols which represent that experience. Using various ways of knowing, each individual constructs a cognitive symbolic representation of reality upon which individual actions are based.

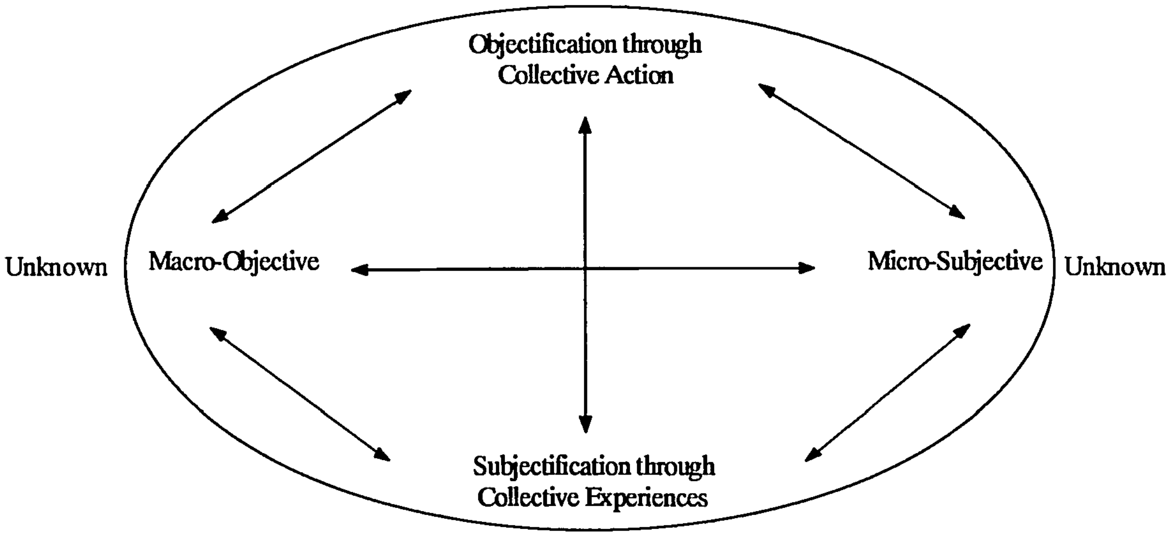

Figure 1. A Post-Newtonian "process" model for the social sciences

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[62] This, in a sense, is an affirmation of realism. Reality, herein, is assumed to exist prior to every individual. This is not the problem—recall Einstein's answer to the philosophical question about the tree falling in the forest. . .

Proposition 1 states that *the more individual experiences are shared and perceived to be similar, the more "real" the resulting symbolic representations become.* It makes no difference whether these experiences reflect "truth" or not. As W.I. Thomas has said, if these things are perceived to be real, they will have real consequences in terms of the resulting human actions. Proposition 2, then, states that *people act based on individual symbolic representations of reality which are always incomplete and seldom an accurate reflection of any ontological reality.* However, as people act on these symbolic representations and assumptions, they actively create and change that ontological reality, i.e., regardless of the integrity of our motivations, our actions have real consequences. Proposition 3 states that *the more people base their actions on common or like symbolic representations of the world, the more objectively "real" those symbolic representations become.* This is what makes science, society, and knowledge possible. Once these symbolic representations form a continuing basis for collective action, patterns of action start to emerge—some would call these patterns "structures," but such a definition tends to artificially separate the actor, action, and context. These recurring patterns catch our attention and form the basis of objective reality.[63] Proposition 4 states that *the more patterns of action and interaction tend to recur, the more likely they are to become part of our collective*

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[63] Also recall Kant's assertion (1781/1934) that, through purposive human interaction with the external world, the reality of ideas (the noumena) tends to actively become the reality of experience (phenomena). The Post-Newtonian perspective would unite these in a fashion similar to that of Hegel, but always emerging from the process of human action and active interpretation instead of assuming some *a priori* order or ideal.

experience over time and space. In other words, through subjectification, these recurring patterns *become* our collective objective reality and form part of the *a priori* assumptions we share about the ontological world. Proposition 5 takes into account the gap between epistemology and ontology. It states that *there will always be phenomena of which we are not aware but still have real effects and consequences.* This is true in regard to our deepest internal motivations as well as in the farthest reaches of external reality, removed from all human experience whatsoever. As in Heisenberg's Duplex Interpretation, this epistemological limit to our everyday understanding forms an *action potential.* It also reaffirms our inability to take all variables into account in our explanations and predictions. Similarly, it is only through our collective actions and experiences that reality is objectified and thus realized.

At the same time, we must recognize that nature can continue to function without human beings if we were to disappear. But even the physicists say that this is not the question. As a part of nature that has evolved to the extent that it can consciously realize itself, we have acquired the ability—through our individual and collective actions—to influence the roll of nature's dice. Nature may unfold like the roll of dice, but we, as conscious products of nature, actively seek to influence the outcome of the rolls to our own benefit. However, our collective vision is limited. As we influence the roll of the dice, we concomitantly eliminate—for better and for worse—potential outcomes for our own future (i.e., we are subject to social entropy).

Nonetheless, the need or desire for order in our world encourages us to pursue a meaningful collective definition and understanding of ontological reality. At the same time, we seek to assure the continuance of our own species by robbing energy and resources from other open systems to cheat entropy in the short run—with long-term implications for the viability of both natural and social processes and systems. Given the vast influence of the human specieis as active observers and participants in the otherwise random outcome of the unfolding universe, ontological reality becomes more of a sociological event than a random outcome of nature's dice. Taking this into consideration, the final proposition in the Post-Newtonian process theory for the social sciences is more an edict than a description of process. Proposition 6 states *human beings are responsible for the world they create*. As sentient, yet corporeal, beings we are bound to the here and now. Even so, the future does not lie in some divine plan or, for that matter, a roll of the dice. It is in our hands. The secrets of the universe are thus, in the final analysis, sociological—they are what we make of them.

APPLICATION: REFLECTIONS ON AN INFORMATION SOCIETY

The dominance of the human species over all others on Earth is the result of two innate human capacities. The first of these capacities is the ability to intentionally adapt the environment to us, as opposed to waiting for evolution to adapt us to the environment. This ability is the basis for *technology*: the utilization of material and nonmaterial resources to alter our adaptive capacities. The second human capacity which has allowed us to rise to a place of dominance in nature is the ability to transform everyday information into symbols and transfer those symbols across time and space. Though other species demonstrate abstract reasoning and are able to communicate using symbols, humans are the only species known to transfer these symbols across generations, thus allowing subsequent generations to not only possess knowledge, but to accumulate it outside everyday socialization and experiences. This is our capacity for collective knowledge, and it is what makes *Science*—the knowledge of, and methods of acquiring knowledge of, the ontological world— possible.[64] For millions of years, these two human capacities worked separately to bring the human species to its present position in the natural hierarchy. However, it has only been within the last two centuries that these capacities have been combined and utilized together—this combining of science and technology is

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[64] "S"cience, as opposed to "s"cience, as mentioned earlier, refers to the pursuit of ontological understanding, utilizes a variety of ways of knowing, and is closer to what has in the past been called "natural philosophy."

one of the defining characteristics of modernity, and has moved us from a hunting and gathering, to an agricultural, then an industrial society. These two basic human processes—adaptive environmental transformation and cultural transmission—are now undergoing a major revolution. Over the last fifty years, the processes of science and technology have joined in such a way that knowledge itself has been manufactured and commodified. According to Bell, "Knowledge is a *social* product and the question of its cost, price, or value is vastly different from that of industrial items" (1973, p. xiv). The *processes* by which we exercise our distinctly human capacities are thus altered by the combining of science and technology and the resulting emergence of an information-based society. The vast success of information technology has changed our world and, consequently, the way we look at it. It challenges some of the traditional ways of understanding human processes and relationships (see Toffler, 1990). At the most basic level, it calls for a new paradigm for the natural sciences as well as the social sciences.

There are three basic indicators of an emerging information society. The first is the breakdown of traditional political, economic, and social structures. On the macro level, these traditional structures are being replaced by global processes of capitalist economic exchange and the globalization of commodity and labor markets. At the same time, traditional political structures are losing dominance in the global arena. Every war now fought is fought in the virtual backyard of every other country on the globe. Local and national exchange structures are being replaced by flexible regional and international agreements such as NAFTA and the EEC. A new multinational corporatism is emerging, linked not by formal structures, but by a network of exchange and decision making processes which affect the economic and political community as a whole. This is made possible by information technology. The need for local structural controls has vanished along with the geographic limits of the decision making process. In 1994, the president of the United States, and also the attorney general, conducted "town meetings" in a virtual reality of computer facilitated "live" communication across time and space. People across the globe engage in virtual communication—even virtual sex—in real time through computer assisted processes and networks of communication. Whether these things are "real" or not is not the issue—they are, as W.I. Thomas precisely pointed out, real in their consequences. The challenge to our traditional ideas about high technology and high science is that such things are thought to be possible only through complex bureaucratic structures and a hierarchy of authority. This is not so in the virtual community, says Howard Rheingold.

> The word *anarchy* is frequently used to describe the Usenet, not in the sense of chaotic and disorganized, but in the sense that the whole enterprise of moving all these words from all these people to all these other people is accomplished with no central governing hierarchy on either policy or technical levels. This grew directly out of the way Usenet postings were designed to be passed around and the loosely coupled UUCP network. From the beginning, there was no emphasis on a central organization. . . . Over time, the ongoing conversations often create communities among the regulars of newsgroups. And other newsgroups are more like battlefields than communities, although they also have their regulars and their [social] norms. (Rheingold, 1993, pp. 119-122).

At the regional, national, state, and local levels we find that traditional political, economic, and social structures have disappeared into a "virtual" interaction process, facilitated by information technology, which knows no structure or bounds. The immediate consequences of this shift bring us to the second indicator of an emerging information society: the shift from resource intensive production to knowledge intensive production.

In the global arena the new form of capital is knowledge (Toffler, 1990). Work, in the economic sense (i.e., adding value to capital) in the global arena now inevitably involves the encoding, transmission, storage, decoding, and interpretation of information and data. Recent advancements in information technology have resulted in an exponential increase in the amount of data available for examination. But data in its raw form is relatively worthless. According to Wurman (1989), the new information economy will be based on the effective and efficient transformation of data into useful information and knowledge. Wurman suggests that work in the information economy will involve turning simple data into information, with information being defined as data that has been organized in some logical manner. Another tier of work in the information economy will involve manipulating that information back and forth between its organized and raw symbolic forms and either storing or transmitting that information across time and space. This is the manual labor of the information age; information becomes the "raw material" of production to be mined, transformed, stored, etc. Information itself, though possessing a "value-added" component, is insufficient to guide us in effective decision making. Information (as ordered and/or categorized data) must be applied to problems and processes in the everyday world. In fact, Wurman equates "knowledge" with the ability to apply information effectively to everyday phenomena. If there is to be a new middle class in the emerging information society, it will, in all likelihood, involve the level of production which turns information into useful knowledge. Normal science is good at knowledge production. The expansion rate of knowledge since the Enlightenment is staggering. However, normal science has traditionally rejected the final tier of production in the new information economy: transforming data, information, and knowledge into *wisdom*. Wisdom takes information and knowledge and places it in a moral-ethical context. This is the new challenge of the information age: to be guided by wisdom in the collection, transformation, and interpretation of data. It is precisely what the Post-Newtonian paradigm is reffing to in its call for sociological variables. Classical Newtonian science rejected the introduction of moral and ethical variables into its epistemology. It removed human consciousness and human understanding from "reality" itself. To exacerbate matters even more, the product, process, and purpose of information production falls outside of the realm of our immediate sensory experience. Thus, Classical concepts do not appear to be of much help in making an effective transition to an information society. The task of translating information and knowledge to wisdom is complicated by the third indicator of an emerging information-based society: the progressive abstraction of everyday life.

If any empirical observations can be made about information society at all, they would have to be that everyday life in information society is becoming more and more symbolic and abstract. The most obvious is in the economy, where money is no longer the primary medium of exchange. People now work every day and never see a direct product or compensation for their labors.[65] Quite often, payroll is directly deposited (no money or paper actually changes hands) in the employee's bank account. Note that no money actually exists there—the record of the account exists only as magnetic symbolic coding on computer disks. When purchasing necessities, the employee may use a magnetically coded card, which transmits an electronic record of the exchange to a central processing facility which, in turn, routes this electronic information back to the employee's bank where a computer adjusts the balance in the virtual bank account. This symbolic exchange of virtual resources occurs at the global level in the same manner as at the local level, with no tangible or visible structure. The process itself only requires an information infrastructure and the faith—repeat: FAITH—of the individuals engaging in the activities. Political processes are also disappearing into virtual realities. Various forms of media produce human experiences for mass consumption which, in turn, transforms each individual's

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[65] Marx would indeed be perplexed by the information economy.

“reality” to reflect this “virtual” representation. Researchers have determined that the strongest agent of socialization on youth is the mass media, particularly television. Thus, human interaction and socialization have also become abstracted into virtual realities. People can longer look to recognizable and tangible structures for the appearance of order. What holds us together—information technology makes this exceedingly clear— is an interconnected web of complex interrelated processes. What does this imply for our everyday lives as producers, consumers, and inhabitants of the real world?

The crisis of an information society is not in the disappearance or virtualization of structure, but in the failure to recognize the primacy of symbolic interactive processes, and in recognizing that our theories and Science need to make this conceptual shift. It also implies a serious responsibility for humans as active creators and participants in the world. If we are, in fact, responsible for the world we create, people need to transform data, information, and symbolic processes into knowledge and the moral context of wisdom. However, it must be recognized that, in this process, information technology can be both enabling and oppressing. The decisions we make now will determine the options we will have left in the future. Still, these sociological variables remain in our control. Now, more than ever, the decisions are up to us.

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