Paper Title: Self-Limitation in Science, Philosophy and Religion
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Abstract:
Self-limitation in Science: The intent of the present work is to re-envision science in order to investigate the possibility of bringing self-reflection to scientific thought. To *decipher* and render intelligible the “mute language” of the history of scientific discovery and technological invention we must attend to the relationship between classical and quantum physics as a metaphor “mutely appealing for an imaginative leap.” Beyond being an elegant example of a scientific revolution, the cognitive transition from classical to quantum mechanics is unique in the history of science. We can learn an important philosophical lesson from the development of quantum mechanics: that our *necessary interaction* with object of investigation—a necessity meticulously defined and defended in terms of quantum theory itself – alters the normative aspect of science. Quantum theory has initiated a new phase in the phenomenology of scientific thought: a phase which provides the conditions for the arousal of normative consciousness *from within* science. In considering the Bohr-Einstein debate we find their disagreements to be about a theory of knowledge and a theory of reality. The nature of the disagreement becomes especially clear in light of Plato’s epistemology, as represented in his “divided line” image. The idea of limit and of self-limitation holds an important place in Plato’s thinking, especially in regard to the relationship between the ideas and ideals.

Science, Myth and Metaphor: We consider Bohr’s reflection that there are moments in science when “language can be used only as in poetry.” We note the central importance of metaphor in language and proceed to examine its role in poetry, science and religion. Myth and metaphor have played important roles in the history of science and the history of religion. While examples of the latter are generally well known, examples of the former are less familiar. A popular belief states that the ultimate rejection of the extravagant claims of alchemy paved the way for progress in objective science. It is perhaps more accurate to say that the alchemical mythos was replaced by the modern mythos of the machine. The mechanistic materialism of the modern age is more powerful and efficient but it is nevertheless equally mythical in scope and ambition. With the rise of 20^{th} century physics many of the ideals and ambitions of modern science were realized, but with victory came renunciation. Bohr’s Copenhagen interpretation of the atom placed fundamental epistemic limits on quantum physics.

Self-limitation in Religion: Choice necessarily brings limitation: making one choice precludes making some other choices – the very point of complementarity. The ultimate paradox, obvious to practitioners of yoga and other spiritual disciplines, is that self-limitation is an exercise of freedom and it brings about liberation. From this perspective it is ultimately self-limiting to not practice self-limitation.

Biography:
Ph.D., Philosophy: Fordham University in (1990)
The Relevance of Myth to Science: Examination of the function of myth and metaphor in scientific concept formation
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Farzad recently received a 3-year grant from the Metanexus Institute, sponsored by the John Templeton Foundation, to direct "The Nexus of Science and Religion," an ongoing series of public events and lectures on the confluence of science, religion, philosophy, music, art, and technology.

He has taught philosophy and/or chemistry for about 20 years. In the 1990s, with support from NASA, he developed a research-oriented Earth system science course for high schools, including some web-based data visualization systems for use by students, teachers, and other non-specialists. His scientific and philosophical studies focus on the importance of systems as they occur in nature and in our thinking about nature.

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Paper Text:

Purpose: The intent of the present work is to re-envision science in order to investigate the possibility of its self-consciousness, that is, of bringing self-reflection to scientific thought. We attempt to explore the relation between scientific and normative thinking. This effort involves listening to the mute language (Vico) of the history of science, the sensual speech (Boehme) of the history of discovery and invention. To *decipher* and render intelligible the sphere of thought generated by the history of science and technology we must read it metaphorically, for example, seeing the relationship between classical and quantum physics as a metaphor "mutely appealing for an imaginative leap" (Whitehead). The history of science may be seen as the process of self- consciousness: the story of the soul understanding itself in the act of trying to understand the world.

In the case of quantum physics science refers directly to itself in the process of making reference to nature. With the development of quantum physics it became necessary to describe the describing system in order to proceed with a clear description of the subject matter at hand. In other words, the instrument must account for itself, the theory must, as a matter of theoretical necessity, compensate for its own epistemological limitation and gain perspective on its perspective. Such terms are familiar in the moral sphere: self-conscious self-reference, self-conscious acknowledgement of one's creativity, and deliberate self-limitation are pre-conditions of moral agency. In this vein, the development of the notion of complementarity in the context of quantum physics represents an important moment of self-reference and potential self-consciousness in the history of science. While it may not serve as a basis for moral agency, in any case, complementarity is a normative standard within the frame of physics.

Introduction: Science and myth have in common a dependence on symbolism. Both achieve their ends by the skillful use of metaphor. Semantic polyvalence feeds imagination. Playing on the natural polysemy of poetic metaphor, mythology elaborates grand cosmological and eschatological schemes. The scientific models with which we interpret the physical world are in fact mathematical elaborations of our metaphorical re-descriptions of phenomena. In science there is a concerted effort to *reduce* the polyvalence of a given term in order to achieve unambiguous communication. However, this tendency toward complete literalization results in its diametrical opposite. Complete literalism in science is impossible and the attempt to achieve it actually encourages the acceptance of the mythos of naive scientific realism. Such enantiodromia is characteristic of unreflective human action and the stuff of ancient Greek tragedy and modern political comedy. Thomas Kuhn has demonstrated this tendency in the context of the history of science by drawing attention to the periodic recurrence of scientific revolutions. In the light of every revolutionary new theory, the literal truths of a previous scientific era come to be seen as the mythological misconceptions of a benighted generation of scientists.

Although every scientist is familiar with the history of science in its broad outlines, it seems that the epistemological lesson of the life-cycle of science has not been grasped by many. According to Thomas Kuhn[1], the “normal” or “puzzle-solving” phase in the growth of science is a steady accumulation of data and consolidation of theories under the guidance of a paradigm. In light of studies in the function of myth, metaphor and model, we can restate Kuhn's notion of normal science as follows: the standard education of a scientist is an *initiation* into the vision of the world available to the believer of the prevailing scientific paradigm. Scientific growth, as the growth of the community of scientists, necessarily involves the mythologization of hypotheses, theories and paradigms. Mythic thinking is a necessary requisite for the growth of a paradigm's intellectual hegemony. Of course *critical* thinking is also a major part of the training, but this particular scientific skill is *normally* to be directed not at the basis of the paradigm but to the process of theoretical and experimental *application* of the paradigm's models to regions other than those for which it was originally designed. Nevertheless it is from the critical investigation of the frontier that anomalies are eventually discovered.

Anomalies are phenomena which do not fit the paradigm and cannot be easily reconciled with it. Occasionally, they arise, persist and accumulate to precipitate a crisis that necessitates the review of the paradigm itself. Heightened awareness of contradictory and paradoxical findings actually help to focus attention on the ‘ungrammatical’ behavior of data. In fact, Bohr explicitly notes that he attended closely to the contradictions of classical physics in order to find his new quantum model of the atom. In addition to the search for contradictions and anomalies, conceptual exploration, epistemological and even metaphysical discussion cultivate a more open, almost ‘pre-paradigm’ phase of science which eventually brings on a conceptual phase change. Kuhn calls this the ‘revolutionary’ science. This stage of the life cycle of science is characterized by intensified mythogenesis, novel use of existing instruments or wholesale invention of new ones. The Bohr-Einstein debates exemplify the explicitly epistemological and metaphysical self-review going on during the twentieth century revolution in physics. This *self-conscious* evaluation of experimental procedures, metaphors and paradigms is the creative phase of the life-cycle of scientific thought. Kuhn called this the "revolutionary" phase of science.

Beyond being an elegant example of a scientific revolution, the cognitive transition from classical to quantum mechanics is unique in the history of science. We can learn an important philosophical lesson from the development of quantum mechanics: that our *necessary interaction* with objects of investigation—a necessity meticulously defined and defended in terms of quantum theory itself – alters the metaethical aspect of science. Quantum theory carefully and clearly circumscribes the objective limit of the old ideal of observer-independent scientific knowledge. In this act of self-limitation, scientific thought has developed the means for its own self-consciousness: quantum theory has initiated a new phase in the phenomenology of scientific thought: a phase which provides the conditions for, and in complementarity the prime example of the arousal of normative consciousness *from within* science.

Historical background of Quantum Theory:

By the end of the 19th century, physicists thought they had nearly achieved a unification of the two pillars of the Newtonian temple: mechanics (the science of the interactions of bodies) and optics (the science of the behavior of light). The unification of the theories of electricity, magnetism and light into a general theory of electromagnetic phenomena was a truly notable triumph. But the attempts to fill out the details of the integration of mechanical and electromagnetic models gave rise to the awareness of a series of anomalies wherever matter and radiation, or their theories, *interacted*.

In 1900 Max Planck postulated a "quantum of action," which determines the minimum possible quantity of energy transfer, enabling him to account for the experimentally obtained frequency distribution, i.e., *the colors* radiated in "black body" radiation experiments. But this success was purchased at the expense of the *continuity* of nature's physical processes. Though it eventually won him the Nobel Prize (1918, for his "discovery of energy quanta"), Planck was not proud of what seemed to be an arbitrary mathematical invention, one that renders natural process as fundamentally discontinuous.

The quantum resisted all efforts to fit into a classical physics framework, and so despite its success at solving a few long-standing puzzles nothing much came of it for a time. Planck's constant had little impact on physics until Einstein used it, in 1905, to successfully explain the *photoelectric effect*, another phenomenon in which the interaction of matter with light had posed difficulties for the integration of the classical theory of matter with the classical theory of light. This effort won Einstein the Nobel Prize in physics (1921). It came to Niles Bohr to apply Planck's quantum concept to the Rutherford model of atomic structure in 1911.This led to a series of remarkably precise explanations and predictions of hydrogen's hitherto unexplained radiative properties, and a Nobel Prize for Bohr (1922).

The investigation of the relationship between matter and light revealed that the energy radiating from matter is restricted to very definite and *discrete* values: matter can emit radiant energy only at certain frequencies *and nowhere in between*. In Bohr's atom, the transitions from one energy level to another cannot occur smoothly but only as "jumps;" each jump is a multiple of Planck's quantum of action. The term "quantum leap" originally referred to the discontinuous transition between atomic energy levels.[2]

So the electron's transition from one energy level, to another one, is discontinuous… so what? The problem is that this transition doesn't really count as motion in the classic Galilean-Newtonian understanding of mechanics: the electron does not go from A to B the way that balls move from the top to the bottom of an inclined plane. The electron seems to disappear from one energy level as it appears at the other one. As A.N. Whitehead put it in 1925: the electron seems to have a discontinuous existence, and so shares something in common with a Tibetan Buddhist monk whose earthly incarnations are intermittent.

The effort to measure the usual things about objects, i.e., position (x), momentum(p), time (t), and energy(E), introduces a new and interesting twist: these variables are *conjugate*, inseparably paired on the quantum level. Heisenberg's Indeterminacy Principle expresses this with mathematical precision, using Planck's constant as the key term, as Bohr notes:

> These circumstances find quantitative expression in Heisenberg's indeterminacy relations which specify the reciprocal latitude for the fixation, in quantum mechanics, of kinematical and dynamical variables required for the definition of the state of a system in classical mechanics.

Bohr goes on to note that this represent a *mutual limitation of concepts*:

> In fact the limited commutability of the symbols by which these variable sare represented in the quantal formalism corresponds to the mutual exclusion of the experimental arrangements required for their unambiguous definition. In this context, we are of course not concerned with a restriction as to the accuracy of measurements, but with a *limitation of the well- defined application of space-time concepts and dynamical conservation laws*, entailed by the necessary distinction between measuring instruments and atomic objects [emphasis added].[3]

The conjugate relation of canonical variables captured in the Heisenberg relations was an unexpected discovery of quantum physics. It sets an absolute lower limit on what can be known about these pairs of variables (t and E, p and x). Bohr employed the term 'complementarity' to characterize this new relationship between the properties of an atomic event. At the classical level these variables are *not* conjugate, as Bohr points out.

> While, within the scope of classical physics, the interaction between object and apparatus can be neglected or, if necessary, compensated for, in quantum physics this *interaction forms an inseparable part of the phenomenon*. [emphasis added][4]

This difference marks the radical discontinuity between classical and quantum contexts. Bohr eventually came to think of complementarity as a new conceptual framework better suited (than classical physics) to understanding situations where the interaction between observing apparatus and observed objects is *constitutive*— and this is what he means by saying the interaction unavoidably "forms an inseparable part of the phenomenon."

Philosophical Implications of Quantum Theory

Bohr asserted that complementarity is necessitated *logically* and categorically by the fact that we are measuring the classical properties of a non-classical object. To put it as simply as possible, measurements of quantum-scale (subatomic) objects show violations of expectations based on classical models depicting atoms as miniature, electrically charged rocks. The full range of experimental results show a pattern that is uninterpretable by means of classical theories. The quantum of action was postulated by Planck to account for this new and different pattern in the behavior of matter. Bohr says something to the effect that the quantum of action is an expression of the unbridgeable difference between classical and quantum realities. As such it is a measure of the inapplicability of classical framework, and so reveals the shortcoming of taking literally the classical realist ontology.

When we say that the observation of atoms is itself a quantum phenomenon, we refer to the unavoidable coupling of two systems: the classical object (measuring device) and the quantum object (the atomic system measured) are joined at the moment of observation. Significantly, the readings are taken *in the language of the instrument*. Thus, though the quantum object is manifestly non-classical in its behavior, we have no recourse but to measure it *as though it were classical*: we register the classical properties of something that is not a classical object

Bohr found this understanding of science most philosophically significant, and indeed, philosophers have argued against the tenability of the naive realist interpretation of physics at least since Parmenides and Plato, and before them in Indian philosophy. Quantum theory expresses this in scientifically precise terms. As such, quantum theory represents a moment in the self-limitation, more specifically, in the self-consciousness of science.

Within the framework of complementarity science itself acknowledges that it is *not a mirror of nature but a myth about it*. Notwithstanding all of the mathematical coherence and logical consistency science, the "as if" remains. This is what Plato meant by calling physical science a "likely story."[5] The Platonic sense of mythical science, as portrayed in his *Timaeus*, amounts to the self-conscious use of non-literal language in order to communicate an otherwise incommunicable situation[6]. Heisenberg, recalling his first conversation with Bohr, quotes him on his attitude toward the poetics of science:

> We must be clear that, when it comes to atoms, language can be used only as in poetry. The poet too is not so concerned with describing facts as with creating images and establishing mental connections.[7]

Sometimes a subtle change of mental connections makes all the difference in the world. In *Atomic Theory and the Description of Nature*, Bohr asserts that *atomicity*, formerly ascribed to the material substrate with its presupposed continuity of spatial temporal endurance, is now to be thought of as the characteristic of *atomic activity*: the changes of state that an atomic system undergoes are quantum changes.

> Taking the indivisibility of the quantum of action as a starting point, the author suggested that every change in the state of an atom should be regarded as an *individual process incapable of more detailed description*, by which the atom goes from one so-called stationary state to another [emphasis added].[8]

The success of the quantum theory of atomic structure rests on "renunciation of all attempts to obtain a detailed description of the individual transition process."[9] Thus for atomic processes "the conceptions of motion are renounced."[10] This is "tantamount to the renunciation of a strictly causal description." But "we must consider this very renunciation as an essential advance in our understanding."[11]

The significance of this renunciation is, in the words of Ernst Cassirer, the abandonment of "the hope of representing the whole of natural happening by means of a single strictly determined set of symbols."[12] The complete description of subatomic entities is achieved only through the use of two logically opposed models: for some purposes the entity is best described as a particle, and in other circumstances as a wave. The famous two-slit experiment sets up a situation where both models must be used to describe the experimental findings.[13] Quantum mechanics must face the necessity of describing the same entity as particle and as wave, undeterred in this use "by the fact that the intuitive combination of these two pictures proves impossible."[14] This means that "the habits and demands of intuitive representation and understanding must be subordinated to this fundamental requirement, namely the connecting of phenomena according to law."[15] The epistemological lesson which Cassirer finds in all of this is quite similar to the one Bohr sees. Cassirer ends his *Determinism and Indeterminism in Modern Physics: Historical and Systematic Studies of the Problem of Causality* with the following general conclusion:

> When, even in science, such a superposition of dissimilar aspects [i.e., of wave and particle models] is necessary, it will be more easily understandable that we shall meet such a superposition again as soon as we seek to realize the full concept of reality, which requires the cooperation of all functions of the spirit and can only be reached through all of them together.

In Bohr's words, "we must, in general be prepared to accept the fact that complete elucidation of one and the same object may require diverse points of views which defy a unique description."[16] We are thus faced with "the necessity of taking recourse to a complementarity, or reciprocal, mode of description," a necessity which, until the advent of quantum mechanics, was antithetical to so-called 'exact science' which is in general, "the attempt to attain a uniqueness by avoiding all references to the perceiving subject."[17] Bohr's notion of complementarity indicates the broad scope of its applicability and necessitates a really new set of scientific expectations, not merely a new set of theories, but something more like a new paradigm of science.

> **Far from restricting our efforts to put questions to nature, the notion of *complementarity* simply characterizes the answers we can receive by such an inquiry whenever the interaction between the measuring instruments and the objects forms an integral part of the phenomena.[18]**

Bohr found that the necessity of self-limitation arises from extending the range of observational science itself. He consistently championed the idea that far from being a refutation of classical physics, quantum theory is its "rational generalization"[19] because it extends the application of the principle of causality to the relation between the observing device and the observed object. Each data-gathering observation is part and parcel of a distinct, whole phenomenon; their unrestricted combination would ignore the context-dependence of each

measurement.

> …[E]vidence about atomic objects obtained by different experimental arrangements exhibits a novel kind of complementary relation. Indeed, it must be recognized that such evidence appears contradictory when combination into a single picture is attempted, *exhausts all conceivable knowledge about the object* (emphasis added).[20]

Thus the *concepts* of classical physics are conserved but the *relationship between them has undergone modification*. What is lost is the nicely visualizable causal space-time picture. "...[W]e must only be prepared for the necessity of an ever-extending abstraction from our customary demands for a directly visualisable description of nature."[21] As we shall see, Bohr is in agreement with Plato on this point: a loss of this sort constitutes a real gain in knowledge.

Self-limitation in Plato's Theory of Knowledge: The "Divided Line"

The idea of limit and of self-limitation holds an important place in Plato's thinking. Socratic doubt, probably the most basic instance of self-limitation is its own reward. The fruits of self-doubt and self-examination are displayed throughout Plato's early and middle period dialogues where Socrates puts right-makes-right bullies to shame at every opportunity.

In his discussion of the levels or modes of cognition, the transition from level to level, or more generally the functional relationship between the levels, is the point of key importance. The ascent to more and more general modes of knowledge is achieved through limitation. Plato illustrates his ideas through a diagram of the four modes of cognition, the "divided line", and then goes on to tell his famous "Myth of the Cave," which is concerned with the ascent of the soul from the depths of illusion to the full knowledge of the Good. The mystical and religious overtones of the Cave myth are hard to miss. Similarities run through the world's religious traditions. One of the most directly similar, the Bodhisattva tradition, amplifies on the meaning, if not the image of Plato's "Cave" myth. At the other end of history, the "Cave" refers to a virtual reality environment for interacting with the broad array of images in an immersive, i.e., virtual, world. In this "cave" seeing is meant to induce learning, believing, or, at the very least pleasure.

Plato's Myth of the Cave tells of a subterranean human race who have spent their lives since early childhood chained to their seats so that they could look in one direction only. In front of them is a wall upon which are cast the shadows of models which are paraded in front of a fire. Because the fire and the models are beyond their visual horizons, they grow in the belief that they see real trees and real horses on the wall, but in reality see only shadows of their models (images of their images). One man is liberated and forced to turn around and view, to his great surprise and pain, the fire (which hurts his shadow-drenched eyes) and the models (which hurt his shadow-ridden mind). Further shock and ever more intense surprise and pain ensue as he is dragged out of the cave up into the world of real trees and horses, all illuminated by the Sun. This ultimate source of the visible world, gives him a whole new sense of vision, and better concepts of visibility, light, reality, and truth. He is eventually returned to the cave where he tries in vain to tell his fellow cave dwellers about reality.

Plato's discussion of the "Divided Line" is the polar opposite of the Myth of the Cave: in sharp contrast to the latter's human concreteness, the line displays the ultimate sparseness of sensual detail. Nevertheless, these two discussions are linked, as we shall see. Imagine a vertical[22] line divided into two major sections: the lower signifies the visible world, ruled by the Sun and the eye (a "skyball" for the eyeball, *Republic* 509d [23]) and the upper section signifies the world of the intelligible. The former can be seen but not thought, the latter can be thought but not seen (*Rep.* 507b).

The upper and lower levels of the line are further subdivided into two sections resulting in four vertically stacked sections which I number starting at the bottom, one through four. The four sections on the left hand represent levels of being, those on the right, levels (modes) of knowing. At each level the mode of knowing corresponds to the mode of being for that level. Beginning at the bottom, on the left-hand side we find shadows, reflections on mirrors and illusions of that sort. On the right-hand side of this level we find "shadow-knowledge": second-hand knowledge corresponding to second-hand realities. The "knowledge" of this level is called guessing, hearsay, or imagination, in that it deals with the images of things.

As we progress to level two, on the left we find the objects of full sensory experience whose images are imperfectly cast onto various materials (at level one). Corresponding to this level of reality is opinion, or belief, *doxa*, the Greek root of "dogma.". This epistemic mode encompasses rules of thumb, at one end of the scale, and religious, moral and aesthetic codes at the other. One may summarize: dogma of any sort, religious or scientific, belongs to this level, for it is not the content but the mode of grasping the content that makes for belief. Thus opinions may be wrong or right, but the unreflective adherent cannot, or cares not to, give an account in either case. The business of level three knowledge, which is called 'understanding', is to give such an account. Plato is no lover of dogma (*Rep*. 506c):

> [H]ave you not observed that opinions divorced from knowledge are ugly things? The best of them are blind. Or do you think that those who hold some true opinion without intelligence differs appreciably from blind men who go the right way?

The transition from level two to level three is most significant because it involves treating the objects of opinion (at level two) as images of something more real (at level three), just as the objects of level one are in fact images of objects at level two. The imaging function is of key importance: the image captures the reality imperfectly and approximately, but captures it nonetheless. To facilitate this transition, Plato suggests that we think of level two objects as images of *the forms* at level three, the lower division of intelligible objects. This level contains what could be called "lower level forms" which constitute geometrical model and the subject matter of mathematical physics.

As far as modern culture is concerned, level three of the line is the pinnacle of knowledge and its paradigm. This is not the case for Plato who notes (*Rep.* 510 d) that "the geometers" do not feel called upon to give any account of their assumptions, "but treat them as self-evident." They treat as axioms what are in fact hypotheses. In other words, Plato asks us to treat the knowledge and objects of level three as images of yet another, higher mode of knowledge.

Level four contains what could be called “higher level forms,” which are at once more general and more limited. Though he does not specify what these are in much detail, it is clear that Plato has in mind the forms of the early dialogues: health, beauty, justice, etc. For beyond level four, and beyond the line as a whole, there stands the form of the Good: Plato’s form of all forms, the final limitation, the most universal and most general form of all, and the condition for the possibility and intelligibility of the rest. To make this point Plato draws upon a comparison of the Good with the Sun, which is the source of the seer, the seen and visibility, and yet cannot be seen directly.

> This, then, which gives to the objects of knowledge their truth and to him who knows them his power of knowing, is the form or essential nature of Goodness. It is the cause of knowledge and truth; and so, while you may think of it as an object of knowledge, you will do well to regard it as something beyond truth and knowledge, and precious as these both are, of still higher worth. [*Rep*. 5 08 e]

From this we may infer that the knowledge of level four most closely approximates, but is not equivalent to, the knowledge of the Good which is "beyond truth and knowledge."

> [Objects of knowledge] derive from the Good not only their power of being known, but their very being and reality; and Goodness is not the same thing as being, but even beyond being, surpassing it in dignity and power. [*Rep.* 509 b]

In simple terms, the forms of level four are *ideals;* this word carries the value dimension essential to this mode of knowledge. The forms of level three may be called *ideas* to signify their intelligible character, but without any necessary connection with value. Note that the Good is beyond the line’s divisions, beyond knowing and beyond being, the source of both.

Having laid down the structure of the line and the terms appropriate to each level, we may proceed to a discussion of the progress of knowledge. Plato focuses on the significant difference in the mode of cognition. The mode of thinking at level three is the so-called "downward dialectic," while that of level four is the "upward dialectic."

> In the first [i.e., level 3] the mind uses as images those actual things which themselves had images in the visible world; and it is compelled to pursue its inquiry by starting from assumptions and traveling, not up to a principle but down to a conclusion [about the actual things at level 2]. In the second [i.e., level 4] the mind moves in the other direction, from an assumption up to a principle which is not hypothetical; and it makes no use of images employed in the other section, but only forms and conducts its inquiry solely by their means. (*Rep*. 510 b)

Plato goes on to point out that while geometers draw or construct actual models of triangles and circles for pedagogical purposes, geometry is concerned with the triangle itself, not its image.

> The diagrams they draw and the models they make are actual things which may have shadows and images [of their own in the section below]..., but now they serve in their turn as images, while the student is seeking to behold those realities which only thought can apprehend. (*Rep.* 510 e)

But regarding level four, Plato says,

> you may understand me to mean all that unaided reasoning apprehends by the power of dialectic, when it treats these assumptions [of level 3], not as principles, but as *hypotheses* in the literal sense, things 'laid down' like a flight of steps up which it may mount all the way to something that is not hypothetical, the first principle of all... (*Rep.* 511 b)

The progress from level three ("understanding" or science) to level 4 (dialectical knowledge, or philosophy) is accomplished by a renunciation of images, chiefly through the acknowledgement of their status *as images.* This kind of knowledge involves the transcendence of models through an understanding of their limitation in much the same way that the framework of complementarity prescribes the limits of the proper use of wave and particle models, and specifies the proper employment (unambiguous use) of classical concepts. Before the advance of quantum theory and its application to atomic structure, the basic concepts of physics were used with no restriction; the physicist "did not feel called upon to give an account of them but treated them as self-evident," as Plato says. Classical physicists took their concepts to be principles and their models to be realities. But Bohr's *generalization* of the concept of causality made it applicable to the interaction between object and instrument, necessitating, in his words, a "*limitation* of the well-defined application of space-time concepts and dynamical conservation laws."

The Bohr-Einstein Debate:

The quantum of energy, that tiny minimum unit of energy exchange, so appreciated for its much needed correction to the science of physics, was to become the source of serious challenge to the very idea of science. Disagreements between Bohr and Einstein were, as Bohr points out in the titles of his articles, more about a theory of knowledge and a theory of reality, rather than about physics, on which they were very much in agreement. Einstein's religious conviction that God does not play dice with the universe and that the human mind can understand the divine mind through understanding nature via mathematics, and his confidence in his own intuitive grasp of nature, all culminate in tragic confluence in his discussions with Bohr over the status of quantum theory. Bohr recounts an episode in their epistemological discussions with Einstein which heralded the end of Einstein's challenges to Bohr. At breakfast, during a conference in the early1930s Einstein had challenged Bohr with yet another in a series of thought experiment designed to violate Heisenberg's Indeterminacy Principle and invalidate his uncertainty relations by enabling the precise measurement of momentum and position of a photon. Bohr responded the next morning with a refutation of Einstein's take on the thought experiment by using Einstein's own theory of energy-mass equivalence. This turning point in their debate is captured by Bohr:

> The discussion, so illustrative of the power of the consistency of relativistic arguments, thus emphasized once more the necessity of distinguishing, in the study of atomic phenomena, between the proper measuring instruments which serve to define the reference frame and those parts which are to be regarded as objects under investigation and in the account of which quantum effects cannot be disregarded. Notwithstanding the most suggestive confirmation of the soundness and wide scope of the quantum mechanical way of description, Einstein, in a following conversation with me, expressed, *a feeling of disquietude as regards the apparent lack of firmly laid down principles* for the explanation of nature, on which we could all agree [emphasis added] [24]

It is very interesting that Bohr uses exactly the terms Plato did in his discussion of level four of the line, of steps "laid down" as principles. In this formulation he captures Einstein's lack of appreciation and distaste for quantum physics and complementarity as "complete" or in any sufficient for giving a real understanding nature. While he appreciates its operational and mathematical power – its success in this was obvious – Einstein considered quantum mechanics an unsatisfactory level three science, since it treats established concepts and "principles," such as causality and determinism, as steps laid down for further dialectic, rather than as firm and absolute "Laws of Nature." Bohr, on the other hand, sees quantum theory's major reconfiguration of the concept of physics as a "generalization" of the idea of causality.

Furthermore, Bohr's statement about Einstein's *"feelings"* is quite telling. On the one hand it correctly identifies Einstein's position as based in a feeling about science, not in the rational, empirical or logical foundations of science. Einstein himself corroborates this in his statements about the essence and purpose of physics being to "know the mind of God." In this relation, Bohr's perception of Einstein's "disquietude" can be seen for the euphemism that it is: Einstein was in fact displeased, perhaps even disgusted, with the notion that quantum theory and complementarity could ever be more than useful mathematical formalism. Bohr's elevation of this new framework of thought to the status of high science was repugnant to Einstein. This emotional investment that Einstein displays with regard to this ideal of science could explain the surprising carelessness with which he plied Heisenberg and Bohr with one failed thought experiment after another. He stopped this interactive mode of problem solving in the late thirties, and engaged in no further direct discussion with Bohr about quantum theory. However this disagreement shaped the quest of his later career to search for a unified field theory in an ultimately unsuccessful bid to supercede the indeterministic and complementaristic basis of quantum physics. Einstien and a small band of eminent physicist opposed the Bohr's interpretation of the quantum, of reality, and of science till the end of their days, while the younger generation of scientists embraced and significantly developed – and continue to develop – applications of quantum theory far and wide.

Einstein's final direct challenge to Bohr cam in the form of an article co-authored with Podolsky and Rosen—the famous "EPR" paper. Bohr's response removed lingering logical and experimental ambiguities and refuted Einstein's notion that quantum theory is incomplete. Having defended quantum theory, he went on to state in positive terms the robust research program that emerges from accepting the primacy of the quantum as a limit of analysis, and of complementarity as an explanatory framework in physics:

> In fact it is only the mutual exclusion of any two experimental procedures, permitting the unambiguous definition of complementary physical quantities, *which provides room for new physical laws*, the coexistence of which might at first sight appear irreconcilable with the basic principles of science. It is just this entirely new situation as regards the description of physical phenomena that the notion of *complementarity* aims at characterizing. [emphasis added] [25]

Later re-formulations of the EPR thought experiment, e.g., in terms of Bell's inequalities, have since been experimentally tested, first by Alain Aspect's team and subsequently by others. In all cases the Bohr-Heisenberg position is confirmed over against Einstein's cherished expectations. While this settled the debate for physics, Bohr's philosophical issues about a new ideal of science did not achieve comparable recognition. Expressly disappointed in philosophers of science to the end, Bohr may have found a companion in Plato.

In the context of the discussion of levels and modes of knowledge in Plato's Divided Line discussion, the upward dialectic of Plato's fourth level is the framework in which the relative status and proper employment of the theories of level three are discovered. While the formuli of classical and quantum physics belong to level three, the framework of complementaristic thinking belongs to level four.

In the progression of the modes of cognition in the divided line, each level somehow restricts and unifies the cognition and object of the level below it. Thus, while there are an indefinite number of illusions (level one) or images of an object, there is only one object (level two). While there are many material instances of circle there is but one concept which they all strive to embody and through which they are all grasped (level three). There are many concepts, like that of point, line, circle, vector, momentum, position, etc., and laws interrelating them: these may be used properly or improperly. Thus while a knowledge of chemical or even geometrical laws may be used to improve human life, the same laws can be used to render it miserable. The normative laws of level four restrict the use of those of level three. These fourth level laws are arrived at dialectically ("upward" dialectic) in an attempt to relate all of the pertinent conditions of a given situation and deploy them according to what is best under the circumstances. The choice of circumstances, their boundary conditions, and relations to the human choice-maker are obviously crucial. No single choice is sufficiently adequate for the comprehension of the whole of human life. As Cassirer points out, science has come to an understanding of the necessity for multiple points of view, each with its own integrity and irreducible to the others.

Science can be understood as normative in a number of senses. To some it would mean driving out religious, mythical or moral significance, to seek only what our instruments can measure. For others: an imposition of certain ethical norms on the application of scientific technology is imperative. In the latter case, both those who seek to impose resist ethical restrictions and those who welcome them a share in the belief that human destiny can be controlled by controlling scientific technology and would seek a future made in their own image.

But complementarity is not normative like ethics or aesthetics. It is normative standard for *scientific thinking* in its re-shaping modes of inquiry and mental connections to "provide room for new physical laws, the coexistence of which might at first sight appear irreconcilable with the basic principles of science." Complementatrity sets limits to valid investigation, and thus guides the research program of science with mathematical formalisms and experimental design protocols. It has done so with sufficient rigor and fruitful application that it continues to be used in contemporary physics[26] with respect to particles that were not yet discovered during Bohr's lifetime: quarks. By setting the limits to empirical investigation, it indicates intrinsic limits to the co-application of key concepts in this context. In any case, complementarity is certainly normative in a purely conceptual sense within science itself. It is a concept which functions as a framework for concepts; it is not so much a theory, but a standard by which co-existing ("co-pertinent") theories are understood and properly employed.

Quantum physics reveals to us the structure of knowledge not in its theories so much as in the relations it finds between them. Thus science instructs philosophy. Cassirer notes that the theories and findings of Bohr and Heisenberg,

> have uncovered a characteristic and decisive feature of the mode of cognition and observation of quantum theory; but this feature seems to me to concern not only the structure and articulation of the physical system itself but even more the basis on which it is founded.[27]

What is this basis? The interaction required for gaining information about the world necessarily makes of us "both spectators and actors in this great drama," as Bohr often said. For Wordsworth, "Poetry is Man in Nature." How familiar this sounds. Recall Heisenberg's account of his first conversation with Bohr about using models to understand atomic structure. Bohr had said,

> 'We must be clear that, when it comes to atoms, language can be used only as in poetry. The poet too is not so concerned with describing facts as with creating images and establishing mental connections.'

(Heisenberg continues)

> I therefore asked him: 'If the inner structure of the atom is as closed to descriptive accounts as you say, if we really lack a language for dealing with it, how can we ever hope to understand atoms?' Bohr hesitated for a moment, and then said: 'I think we may yet be able to do so. But in the process, we may have to learn what the word "understanding" really means.'[28]

The necessity of using images and words for understanding realities which are essentially unlike those instruments can only be mitigated by understanding the limits of such an attempt, and by a concerted effort to define such limits by suitable refinements of image and language. The language-user, acknowledging his fate as myth-maker and poet, understands that while demythologizing is impossible, careful remythologizing is obligatory. Plato knew this; it is evident in his refashioning of classical Greek mythology in every one of his dialogues. It is this same sense which underlies Bohr's "conservativism" with respect to the basic concepts of classical physics. Bohr exposed the mythology of classical physics but did not reject it utterly. He recast the original Greek sense of *atomicity* as a statement of renunciation, and he reinterprets the sense of limit. With Einstein as his coping stone, Bohr tried to make clear that the *epistemological* significance of the atom has been mistaken for its *ontological status*, and only by attending to the epistemological status of atomicity may we infer the ever-shifting ontological significance of "the Dance of Being" so neatly illustrated in Feynman diagrams of subatomic processes.

Dialectical reasoning, i.e., Plato's level four thinking, refrains from proclaiming itself to be absolute knowing, and transforms any conceptual mooring into a "step laid down." As mentioned earlier, Einstein expressed "a feeling of disquietude" about quantum theory's "*apparent lack of firmly laid down principles for the explanation of nature.*" To the end of his life he refused to treat the principles of science, or rather, his classical expectations regarding the principles of science, as temporary steps laid down. His unwillingness to accept the complementaristic limitations on physics was based in his unshakeable faith in the ultimate determined order of God's mind. Einstein rejected quantum theory saying, "God doesn't play dice with the universe," to which Bohr responded, "Einstein, stop telling God what to do!" Einstein believed science had granted him a glimpse of God's mind and this shaped his idea of science. Einstein once said of Bohr, "He utters his opinions like one perpetually groping and never like one who believes himself to be in possession of definite truth."[29] This is indeed the appropriate attitude of a man of faith who has given up trying to read the mind of God, and tries to content himself, as Socrates did, with a better understanding of himself. The Socratic philosopher is *never* wise only a devoted *lover* of wisdom, and always a seeker.

What Science and Religion Can Learn From Lyric Poetry

Let us consider again Bohr's reflection that there are moments in science when "language can be used only as in poetry." If we are to take this seriously it behooves us to investigate how language functions in poetry. We must note the central importance of metaphor in language and proceed to examine its role in poetry, science and religion.

Cassirer traces the origin of language to 'radical metaphor'. He differentiates this from the traditional idea of metaphor as the mere transference of the name of one kind of object to another object of a different kind. For Cassirer *transmutation* is the characteristic of radical metaphors: "This involves not merely a transference, but a real *metabasis eis allo genos*; in fact it is not only a transition to another category, but actually the creation of the category itself."[30] He finds in metaphor the origin-spark of verbalization, the birth of the word (*verbum*). As such, metaphor is the *vas hermeticum*, the alchemical vessel of language, for

> …even the most primitive verbal utterance requires a transmutation of a certain cognitive or emotional experience into sound, i.e., into a medium that is foreign to the experience, and even quite disparate; just as the simplest mythical form can arise only by virtue of a transformation which removes a certain impression from the realm of the ordinary, the everyday

> and profane, and lifts it to the level of the 'holy,' the sphere of mythico-religious significance.[31]

According to Thomas Kuhn, the process of scientific discovery, as well as that of science education, involves exactly this kind of transmutation, whereby certain observations, experiments, or even thought experiments are raised to the level of scientific significance. These are moments in the history of science, in scientific cognition when "seeing" is transmuted into "seeing as." Kuhn refers to this process as 'dubbing', 'tagging', 'introducing', 'baptizing', and initially characterizes it a "metaphor-like process" that is more fundamental than the similar process operative in metaphor. He seems to have in mind Cassirer's idea of 'radical metaphor' since he says that this process provides "the link between language and nature".[32] Kuhn finally drops the distinction between metaphor and "metaphor-like process," stating that metaphor "refers to all those processes in which the juxtaposition either of terms or of concrete examples calls forth a network of similarities which help to determine the way in which language attaches to the world."[33]

Cassirer presents an eloquent description of the moment of self-consciousness in milieu of lyric poetry, akin to that of the scientific imagination. Self-consciousness of our own creative power is latent n our most primitive verbal utterances and mythical significations. In lyric poetry this potential moves toward actualization:

> Word and image, which once confronted the human mind as hard realistic powers, have now cast off all reality and effectuality; they have now become a light bright ether in which spirit can move without let or hindrance. This liberation is achieved not because the mind throws aside the sensuous forms of word and image, but in that it uses both as *organs* of its own, and thereby recognizing them for what they really are: forms of its own self-revelation. [34]

Although in this passage Cassirer refers to the "aesthetically liberated life" exemplified in lyric poetry, the same ideal applies to the case of science as well, for

> lyric poetry is not only rooted in mythic motives as its beginning, but keeps its connection with myth even in its highest and purest products… The spirit lives in the world of language and in the mythical image without falling under the control of either.[35]

This is the spirit of Bohr's concept of complementarity, which lives in the world of the mythical concepts of classical physics but keeps its connection with them without falling under their sway. It somehow "rides above" them, as Plato might say, like the charioteer of the *Phaedrus* dialogue.

There are similarities between science and lyric poetry and, of course, important differences. For Cassirer, the world of poetry is "a world of illusion and fantasy– but it is just in this mode of illusion that the realm of pure feeling can find utterance, and can therewith attain its full concrete actualization."[36] The 'objectifying power' of the lyric poet discards all material constraints and it is here that science and poetry must diverge. For although science, like poetry, ought to treat its own language and its own myths with aesthetic detachment, its use of these instruments must accompany a deep concern for material constraints discoverable only through experimental *interaction* with the world. When this concern is set aside science relapses into mythology lyrically played out, sometimes with tragic results, through the preoccupations of any given generation. One need only to recall the conceptual framework that supported 20th century theories of racial superiority and a host of more subtle aberrations in the history of scientific thought. This primitive way of thinking about "other races" has shaped much of history, so it is not surprising to see it cropping up in science and religion, and at points guiding them to convictions unfounded in reality, and actions untethered by morality.

Self-limitation in Religion

Religious dogma shares with Plato's level two of the line and Kuhn's 'normal science,' that mode of unquestioned and unaccounted belief in certain foundational metaphors and models. Many models are accounted for, that is, reasons can be supplied and understanding can be justified, and others are not. Pure dogmatic thinking requires assent, not understanding. "Pure" dogma does not distinguish between opinion and that on which one opines: it is what I think it is, and "thinking" can be removed from the equation.

In Plato's Divided Line dogma, belief unsupported by reason, characterizes the mode of knowing at level two. It makes no difference to this mode of thinking whether the content of the opinion is revealed by science or by myth, whether it is true or false. Socrates and Plato urge us to treat as images those hard solid objects of the world, and to treat as mythical our hard and fast dogmas. It is only by examining dogma, finding its limits, specifying its conditions, etc., that the mode of thinking may change from opining to understanding. Though not always intended as starting points for discovery and exploration, the contradictions inherent in every dogmatic tradition can give rise to change over time.

Let us consider extending Plato's divided line treatment to theology what we demonstrated in the case of science. Our conclusions would be similar. The progress of the soul from one level of the line to another lies in recognizing that the objects and modes of knowing at each level are imperfect and limited images of objects and modes at a higher level. Improvement of thinking, what Plato called 'recollection', is ultimately accomplished by a renunciation of all images, chiefly through the acknowledgement of their status *as images*, of opinions *as opinions.*

This kind of thinking involves the transcendence of all models: in Zen, the Buddha on the road is killed, Christianity discards the filthy rags of righteousness, the sacred clowns of Native American traditions reverse and ridicule all that is sacred, and so on. And in quantum theory the *laws* of classical physics are recognized as *concepts* with limited application.

The divided line itself is an image that must be renounced in practice. The cave is a myth that must be used appropriately, where it is meaningful. By calling his myths *myths,* Plato keeps us from dogmatizing, yet by making them memorably rich and beautiful he keeps us from forgetting them: we are given "a way out" but we are not forced to take it. The liberated man in Plato's myth of the cave must return and then strive to go back up again, arm in arm with unwilling friends, only to return back down again and so on. For Plato, the best way out is by self-discovery of the limits of our beliefs and knowledge through dialogue. And dialogues are all he leaves to us. The understanding embedded in these images of transcendence is that the life of the mind is never static and thus movement between modes of knowing, both up and down, is inevitable and necessary. The Myth of the Cave is so obviously a myth that it cannot be taken literally, yet it enables us to reject the image of line itself, for the line and its divisions is ultimately not as important as the *transitions* among its different levels.

Whitehead is in accord with Plato's view that the highest responsibility of the thinker is to examine assumptions and principles, to treat them as hypotheses and to test their limits. Whitehead's most basic view of the dynamic relationship between science and religion in history is that despite, and actually because of the radical difference in how they approach the world, each can reveal where and how the other periodically exceeds its appropriate boundary. They often have areas of shared concern, but each comes to that point with a different sense of significance. This difference (apparent contradiction) necessitates an examination of basic assumptions that may have hardened into myths.

In some theologies the believer is endowed with freedom and therefore owns the responsibility to choose. If souls are not free the cosmic cycle is just a drill, and the eschaton is a forgone conclusion. Without freedom there is no choice, simply blind mechanism executing a pre-determined and predestined script. Choice necessarily brings limitation: making one choice precludes making some other choices. This is the very point of complementarity. With freedom and limitation come fallibility, humility, and a responsibility to examine, listen and to bathe their opinions in the fires of dialogue.

In the realm of spiritual and humanitarian ideals shared by all peoples, altruism is one important universal ideal. It is hard to find a more obvious and striking example of self-limitation than self-limitation for the sake of another. Fundamentalism, in its most basic sense of having the One True Word, and designating all others as False, serves its followers as the very paradigm of self-limitation. To the designated "others," however, fundamentalism is or the very opposite of self-limitation, being concerned rather with limiting, in the ultimate sense of *negating*, the worth of all others. Yet, it is not so simple as it seems. Though harmful in other ways, fundamentalism's most extreme mode substitutes altruism for the suicide-bomb. This strange and certainly tragic juxtaposition of altruism and fundamentalism illustrates the lethal power of myth.

The ultimate paradox, obvious to all practitioners of yoga and other spiritual disciplines, is that self-limitation is an exercise of freedom and it brings about liberation. From this perspective it is ultimately self-limiting to not practice self-limitation. The key term here is 'practice.' Faith is a practice that is ever-challenged, must be examined and renewed, is never owned, and must be won at every moment. Whenever one loses one's faith one never finds the same faith again: and this is how faith at its best ought to be. We are "fallen," fallible, and deluded and we ought to be *growing* in faith. Neither science nor faith is "all grown up." Admission of a lack of faith, of a loss of faith is the essential moment in growing back toward God, and growing in faith, only to fall again: *O Felix Culpa*! In Plato's *Phaedrus*, as well as in Christian and Sufi mysticism, the lover's longing for the beloved mirrors the soul's longing for its source: and *not* having the beloved is the dynamism, the drive and purpose of life. In this mythos, Life is defined by this *process*.

Note that it is nearly impossible to discuss this without adopting the mindset and language of myth. Like the electron in transition, myth disappears and reappears.

Demythologization calls for its opposite motion of remythologization. Somehow we are passionately attached to any given moment on the path while dispassionately recognizing that these are merely steps along a path. So we are back to Plato and Buddha: the liberated cave-dweller having seen reality returns self-consciously to illusion. The Bodhisattva's attainment of wisdom shows the world and its suffering to be illusion: only the void is ultimately real. But compassion moves the Bodhisattva through many lives to "return" and help "fellow sufferers."

Though far humbler than these lofty purposes, quantum theory shows that while classical concepts cannot hold the essence of reality they also cannot be dispensed with: only our conviction in their absoluteness must be renounced. The lesson of complementarity is the recognition that the line between observer and observed is moveable and that knowing where the line is and knowing the specific consequences of moving the line one way or the other, is of the utmost and crucial importance.

The lines between self and other, life and death, creation and invention, have been trampled by adherents of both theology and of science. Humility, fallibility and responsibility should be the hallmarks of both, rather than fraud, cover-ups, and maintenance of the status quo. Science and theology ought to be in rapt dialogue about these issues in order to maintain focus on growth.

Notes:

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[1] T.S. Kuhn, *The Structure of Scientific Revolutions,* U of Chicago Press (Chicago: 1970).
[2] It is interesting, and more than coincidental that even though "quantum leap" was already metaphorical in its reference to the structure of the atom, pop culture changed its metaphorical reference and the term quickly came to imply radical cognitive change. In much the same way the term "Copernican revolution" originally referred to Copernicus's idea that the Earth, instead of being fixed in space *revolves* around Sun, but from the 18th century onward (thanks to Immanuel Kant) it came to mean "radical cognitive change." At this point let us simply note the assimilation of cosmology and physics into psychology and epistemology, and will return to this intriguing idea in a separate paper.
[3] Bohr, *Essays, 1958-1962, on Atomic Physics and Human Knowledge,* John Wiley and Sons (New York: 1963), 5.
[4] Ibid., 4
[5] Plato, Timaeus 29 d. All passages from Plato (except those from the Republic) are from: E. Hamilton and H. Cairns, eds., Plato: Collected Dialogues Princeton University Press, (Princeton: 1961).
[6] Plato, *Phaedrus* 276c-e, *Letter VII* 341c.
[7] W. Heisenberg, Physics and Beyond, 41.
[8] Ibid.
[9] N. Bohr, "The Quantum of Action and the Description of Nature," in Atomic Theory and the Description of Nature, Cambridge University Press (London: 1961), 109.
[10] Ibid. 113
[11] Ibid. 114
[12] ibid 115.
[13] The experiment arranges conditions such that the electrons leave the source one-by-one (i.e., as particles); in between the source and the target screen is another screen with two

narrow slits through which the electrons must pass. Each leaves a single dot on the target screen, but the pattern they collectively leave is an interference pattern which can be explained only on the assumption of the wave-like nature of the electron. See Heisenberg, Physics and Philosophy, 51-2, and R. Feynman, et al., The Feynman Lectures on Physics III Addison-Wesley, (Reading, MA: 965), 1.4-1.7.

[14] Cassirer, Determinism and Indeterminism in Modern Physics, 212.

[15] Ibid., 212-13.

[16] Ibid., 213

[17] Ibid., 213

[18] Bohr, Essays 1958-1962, 4.

[19] Ibid.

[20] Ibid., 4.

[21] N. Bohr, Atomic Theory and the Description of Nature. 114.

[22] Plato does not refer to vertical or horizontal orientation. I choose vertical because this designation is consistent with and supports the main point of the discussion of "upward and downward" dialectic, which follows.

[23] All passages from Cornford's translation of Plato's Republic from: Greek Philosophy: Thales to Aristotle, R. E. Allen (ed.), Free Press (New York: 1985).

[24] A.P.French and P.J Kennedy, *Niels Bohr: A Centenary Volume*, Harvard U. Press (Cambridge: 1985) p.134

[25] Ibid., p139.

[26] Two recent examples: Prof Christ at Hampton University uses the complementarity between quark and hadron-based descriptions of observables, and states that the experimenter can use either set of complete basis states to describe physical phenomena. Steve King provides a different example in which his experimental data suggests pairings of quark and lepton mixing angles that may provide "clues to quark-lepton unification or quark-lepton complementarity," and prescribes measurements of neutrino mixing angles "to at least the accuracy of the measured quark mixing angles."

[27] Cassirer, Determinism and Indeterminism in Modern Physics, 114.

[28] W. Heisenberg, *Physics and Beyond*, Harper-Row (NY: 1971) 41.

[29] French (1985), 185: Einstein quoted in H. Woolf, *Some Strangeness in the Proportion.*

[30] E. Cassirer, *Language and Myth,* Dover (NY: 1946) p.88.

[31] Ibid. p.87- 88

[32] Kuhn, T.S., "Metaphor in Science," in *Metaphor and Thought*, ed. A. Ortony Cambridge University Press. (NY:1978), p.412.

[33] Ibid. 415.

[34] Cassirer (1946), p.99.

[35] Ibid.

[36] Ibid. p.36.