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Quantum Reality: Some Implications for Christian Theology

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QUANTUM REALITY: SOME IMPLICATIONS FOR CHRISTIAN THEOLOGY

A Thesis
Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Divinity

by
Charles Chinyoung Choo
July 1993

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FOR CHRISTIAN THEOLOGY

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ABSTRACT

QUANTUM REALITY: SOME IMPLICATIONS FOR CHRISTIAN THEOLOGY

by

Charles Chinyoung Choo

Adviser: Fernando L. Canale

ABSTRACT OF GRADUATE STUDENT RESEARCH

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Title: QUANTUM REALITY; SOME IMPLICATIONS FOR CHRISTIAN THEOLOGY

Name of researcher: Charles C. Choo

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Problem

Science (and also the myths concerning science) plays a dominant role in contemporary society. In this study, the epistemological implications of quantum physics were investigated in order to clear away some of the myths concerning science.

Method

Quantum mechanics was studied. After analyzing the basic postulates of quantum mechanics, several interpretations of the theory were examined. From quantum mechanics and its interpretations several epistemological implications were drawn.

Results

Several myths concerning science were identified. These include permanence of science, reductionism, determinism, absoluteness of logic, subject-object dichotomy, and the reality of the objects of a scientific model.

Conclusions

It is important for theologians to be aware of the myths concerning science. The main benefit of quantum mechanics for theologians is in clearing away these myths from the metaphysical conceptual space of theology.

To my wife Jeannie Okyeun and

my daughter Charlene Hiewon

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CHAPTER I

INTRODUCTION

The Issue

Science[1] still continues to play a dominant role in contemporary society. According to Langdon Gilkey, "the most important change in the understanding of religious truth in the last centuries--a change that still dominates our thought today--has been caused more by the work of science than by any other factor, religious or cultural."[2] To many people the term 'science' has come to denote something authoritative, reliable, or correct. Science for some has come to be viewed as the final arbiter in any intellectual pursuit, including theology. Specifically, according to positivists "it is only in the sciences--and especially in physics--that we have anything that can properly be called knowledge."[3] This is nothing new; even the earliest response of theology to science was to make discoveries of science the *basis* of

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[1]The term 'science' is used to denote physical science in particular, not*Wissenschaft*, or scholarship in general.

[2]Langdon Gilkey, Religion and the Scientific Future: Reflections on Myth, Science, and Theology (New York: Harper & Row, Pub., 1970), 4.

[3]W. T. Jones, The Twentieth Century to Wittgenstein and Sartre, 2d ed., A History of Western Philosophy, vol. 5 (New York: Harcourt Brace Jovanovich, Publishers, 1969), 220.

Christian theology, as exemplified by Robert Boyle and William Paley.[1] Even recently, theologian David Tracy proposed that "to continue to uphold a literal interpretation of the Genesis account is simply and irrevocably impossible for anyone who accepts the findings of the modern physical and life sciences."[2]

Theology, as an all-inclusive discipline, can afford to neglect to examine such a claim at its own peril. It is not to impose theology as the 'queen' of sciences, which Stephen Toulmin advises against; rather it is to reserve some critical foothold from which one can study the significance of science in religious perspectives.[3] Also it seems wise to heed the warning of Jürgen Moltmann and avoid isolationism: "Whatever isolates itself, petrifies; and whatever petrifies, dies."[4] The seriousness of some theologians and philosophers concerning this endeavor has been demonstrated by some recently held conferences.[5]

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[1]C. A. Russell, "Science and Theology," New Dictionary of Theology (1988), 626.

[2]David Tracy, Blessed Rage for Order: The New Pluralism in Theology (New York: Harper and Row, Publishers, 1988), 5.

[3]Stephen Toulmin, "The Historicization of Natural Science; Its Implications for Theology," in Paradigm Change in Theology: A Proposal for Discussion, ed. Hans Küng and David Tracy, trans. Margaret Köhl (New York: Crossroad Publishing Company, 1991), 238.

[4]Jürgen Moltmann, "Theology in Transition--To What?" in Paradigm Change in Theology: A Proposal for Discussion, ed. Hans Küng and David Tracy, trans. Margaret Köhl (New York: Crossroad Publishing Company, 1991), 222.

[5]For example, see Hans Küng and David Tracy, eds., Paradigm Change in Theology: A Symposium for the Future, trans. Margaret Köhl (New York: Crossroad Publishing Company, 1991); James T. Cushing and Ernan McMullin, eds., Philosophical Consequences of Quantum Theory: Reflections on Bell's Theorem (Notre Dame, IN: University of Notre Dame

This issue came closer to home for theologians when various so-called "scientific methodologies" such as historical criticism, "demythologization," etc., developed within theological circles. This issue has become a urgent problem for theologians to understand.

The Scope of the Thesis

Before considering the issues involved, an important distinction needs to be made between 'theoretical science' and 'observational data.' Observational data include what we perceive both with and without sophisticated experimental apparatus. Theoretical science by contrast deals basically with models and theories that try to 'explain' the data. The statement "the sky is blue" is an observational statement provided we agree on the meaning of 'sky', 'blue', etc., but in saying "the blueness of the sky is due to the scattering of light from the air molecules," one is already venturing into the realm of theoretical science. The scope of this paper is limited to theoretical science.

Although quantum mechanics is employed as an illustrative example, the aim of the present work is to use this particular theory to elucidate some features of the method of science itself. The conclusions of this paper, it is hoped, will help to eliminate some myths about science.

The pertinent question to raise is this: What is the extent of applicability of science to theology in particular, and to what extent must theology itself be "scientific"? In other words, is there something in the process of science itself that *requires* conformity from theology? More specifically, the question is addressed to the issue of permanence of scientific

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Press, 1989); John M. Mangum, ed., The New Faith-Science Debate: Probing Cosmology, Technology, and Theology (Minneapolis, MN: Fortress Press, 1989).

models, reductionism, determinism, the reliability of logic, subject-object dichotomy, and reality of accepted scientific models. The above characteristics are generally accepted as the hallmark of science. Therefore, it is important to see if this general opinion is warranted.

The Organization of the Thesis

This paper is organized as follows. First, quantum mechanics is introduced. The treatment of the subject is brief and technical terms are kept to a minimum. Then several interpretations of quantum mechanics are introduced. Finally, several general conclusions with their relevance to theology are discussed.

CHAPTER II

AN INTRODUCTION TO QUANTUM MECHANICS[1]

Description

Quantum mechanics, in short, is the physics of the microscopic world, the world of protons, neutrons, electrons, photons, etc. Previous to the emergence of quantum mechanics, it was commonly believed that Newtonian physics, a time-tested highly successful theory, gives an adequate description of the universe including the microscopic world. But it is now well established that Newtonian physics is grossly inadequate to account for the microscopic phenomena.

One of the most intriguing things about the universe at this level is that the microscopic "objects" such as protons, electrons, etc., seem to behave in ways that contradict our common sense, that is to say, our ordinary way of

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[1]The material in this section is fairly familiar within the physics community. But since this paper is written with non-physicists in mind I have adapted the material to the appropriate audience. The following books are recommended for anyone who wants to study the material in depth. For a person who feels uncomfortable with mathematics these books are recommended: Nick Herbert, Quantum Reality: Beyond the New Physics (Garden City, NY: Anchor Press, 1985); Alastair I. M. Rae, Quantum Physics: Illusion or Reality? (Cambridge, England: Cambridge University Press, 1986) . For those who are mathematically initiated, the following books are recommended: Leonard I. Schiff, Quantum Mechanics, 3d ed. (New York: McGraw-Hill, 1955); Claude Cohen-Tannoudji, Bernard Diu, and Franck Laloë, Quantum Mechanics, vol. 1, trans. Susan Hemley, Nicole Ostrowsky, and Dan Ostrowsky (New York: John Wiley and Sons, 1977).

looking at reality. It was Niels Bohr, one of the main architects of quantum mechanics, who said that "anyone who has not been shocked by quantum physics has not understood it."[1]

The Two-Window Experiment

It seems reasonable, at this point, to first look at the basic constituents of this microscopic world. Most people conceive of protons, electron, etc. as somewhat like billiard balls or tennis balls of different sizes. In order to see whether or not this conception is adequate, a thought experiment[2] is utilized. One may imagine a room with two open windows installed side by side with a white wall divider installed parallel but close to the windows. And one may further imagine that some people were provided with several thousand tennis balls with wet red paint on them. If these people (positioned outside the room) threw the balls toward the windows, some of the balls would enter through the windows and hit the wall divider. At the end one would expect to find red paint spots in two general areas on the white wall divider right behind the two windows (figure 1).[3] There is nothing surprising in this result.

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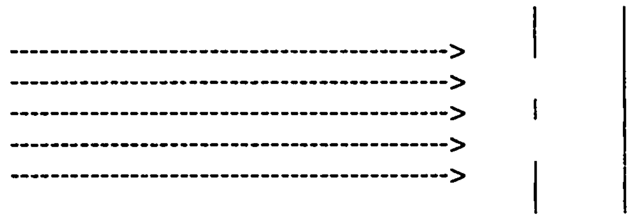
[1]Niels Bohr, quoted in Ronald C. Pine, Science and the Human Prospect (Belmont, CA: Wadsworth Publishing Company, 1989), 214.

[2]A thought experiment is a device used by theoretical physicists to demonstrate the logical consistency, the philosophical implications, etc., of a conceived situation without actually carrying out the experiment. The results of the thought experiment in this section, however, have been well established experimentally. Therefore, the thought experiment here is used for a pedagogical purpose.

[3]There are numerous illustrations of this experiment. For more detail, see the excellent discussion in Richard Feynman, Robert Leighton, and Matthew Sands, The Feynman Lectures on Physics, vol. 3 (Menlo Park, CA: Addison-Wesley Pub. Co., 1965), 1-4 to 1-9.



tennis balls windows wall

Figure 1. Diagram for the tennis ball experiment.

One may further repeat the experiment, this time blind-folding everyone (including the spectators). Even though the two spots may be fainter (since the "throwers" are more likely to miss the windows because they cannot see) we would still expect the same two spots to appear on the wall after the experiment.

<u>The Double-Slit Experiment and Difficulty</u>

If electrons are somewhat like tennis balls one would expect to find analogous results under similar circumstances. For all other non-blind-folding cases,[1] the experimental results are easily explainable by assuming that electrons do behave like tennis balls. But when one performs this "double-slit" (a slit is simply a "window" for electron, that is, a microscopic window) experiment by bombarding electrons without measuring which of the two slits the electrons go through (corresponding to the 'blindfold' experiment) one gets an interference pattern (a series of evenly spaced spots instead of two spots behind the two windows). The cause for such an

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[1]For example, if one "window" is blocked, there appears basically one spot, etc.

interference pattern is shown to be a wave.[1] But this presents a conceptual difficulty; how can electrons behave like a wave, especially since electrons do behave "almost" like particles? One possible explanation is to say that electrons behave like water molecules in an ocean wave. That water is composed of water molecules is well known. Therefore, it is clear that each molecule can be considered to be particle-like (that is, like a tennis ball), yet water molecules may collectively behave like a wave (ordinary water wave). This amounts to saying that the tennis balls used in the thought experiment collectively might act like a wave producing a series of paint spots on the wall.

One may go further with this thought experiment to test if this idea is feasible. If this is the true picture of electron's behavior, we could test it as follows: if the tennis balls are cast one by one, any collective influence can be eliminated thus producing non-wave like behavior, that is, two spots near the two windows. But when this double-slit experiment is performed with one electron passing through the slit system at any one time[2] (corresponding to throwing a tennis ball at one time through the two-window system), we still obtain an interference pattern. This produces a serious difficulty with the particle picture of the electron. Since in other experimental set-ups the electron's behavior is consistent with the particle picture, physicists named this strange behavior "wave-particle duality." No one really knows how to reconcile this strange picture with ordinary conceptual images and categories.

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[1]This is not to say that other factors cannot cause such an interference pattern. It is to say that, as far as the present state of knowledge of physics is concerned, a wave is the most natural explanation for such an interference pattern.

[2]It is technologically possible to perform this by reducing the intensity of electron beam.

One encouraging aspect of this conundrum is that not only electrons, but also protons, neutrons, photons (light), etc., behave in the exact same manner. Some even call these "particles" as "wavicles," that is to say, they are not particles nor waves but sometimes act like particles and sometimes as waves. In layman's terms, physicists do not really have a coherent picture (that is, consistent with "common sense") of what these wavicles look like. It is, therefore, understandable why ever since the emergence of quantum mechanics there have been endless debates on what the theory "means." This is in stark contrast with Newtonian physics which had, relatively speaking, a straightforward "meaning."

Scientific Methodology

Because quantum mechanics presented conceptual difficulties, there have been many objectors to quantum mechanics, including Albert Einstein, who uttered the famous statement, "God doesn't play dice." Since the status itself of quantum mechanics as a scientific theory is questioned (though not its successfulness), it is instructive to look at the method of science itself.[1] Details aside, basically the process of science can be said to begin with observation. Then in order to explain what is observed one proposes a hypothesis. Then the consequences of the hypothesis are tested. A negative result may lead to either the discarding of the hypothesis or a modification of it. A positive result allows one to go through the loop all over again. It is interesting to note that the number of times one has to go through the loop before the status of the hypothesis becomes elevated to that of a theory is arbitrary. In other words, this is an infinite loop.

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[1]For a concise discussion of the structure of science, see Pine, 42.

One may also observe that what are actually tested in science are the consequences of a hypothesis, not the hypothesis itself.[1] One may observe that things drop to the floor, but what is observed is *not* gravitational force itself but it *may* be understood as a consequence of the idea of gravity.[2]

Also one observes that any "theory" is tentative in that there is no point when one can say that a particular scientific model has been proven. In fact, the very concept of "proof" is a mathematical concept which is valid only in mathematical systems. In other words, we have chosen to accept something as "proof" within that relatively "perfect" and highly "artificial" system. Mathematics does not have to correspond to reality. But there is more of the "untidiness" of reality when it comes to science.

Moreover, there is no criterion to determine if an idea is acceptable except the workability of the hypothesis. In other words, if I assume that there are pink elephants all over the universe and assign precise and testable properties to them which explain the data at hand, it is accepted as a good scientific model. It is interesting to note that if one takes this hypothesis of pink elephants seriously then the first thing one has to do is to make the elephants invisible in order to make it consistent with observational data (we do not *see* these pink elephants after all).

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[1]It is important to be reminded that only theoretical science is concerned here. That there is a moon is an observational "fact," but that there is an atom is a theoretical statement since it is impossible for atoms to be seen in the ordinary sense because the dimension of an atom is much smaller than the visible wavelength. (In order to be seen, the dimension of the object must be comparable or larger than the wavelength of visible light since the light has to reflect off the object and enter the eye in order to be seen by human beings.)

[2]It is interesting to note that in general relativity one introduces a curvature of spacetime instead of gravitational force. In other words, there is no such thing as gravitational force in general relativity.

Five Postulates of Quantum Mechanics

In quantum mechanics, there is something akin to this theory of invisible pink elephants. This is called the wave function. Thus we come to the first postulate of quantum mechanics.[1]

The First Postulate of Quantum Mechanics

In quantum physics, a physical state is described by a wave function. This is not an ordinary wave that one can see, but an unobservable one. The amplitude of this wave at a point in space is related to the probability of finding the associated "wavicle" there.[2] This picture is alien to the Newtonian picture and also to common sense. In ordinary physics, in order to describe a ball, one only has to note where the ball is (position) and how fast and in which direction the ball is moving (velocity). But in order to describe an electron, physicists use a mathematical function that describes the distribution of the "wave" throughout space. In order for this "pink elephant" theory to be useful there must be a way to know how the elephants move. This is accomplished by the second postulate.

The Second Postulate of Quantum Mechanics

The time evolution of the wave function is governed by the Schrödinger equation. One would expect this equation to be different from the classical equation which describes how a tennis ball moves. But up to

[1]Those who are interested in a more rigorous presentation of these postulates may refer to Cohen-Tannoudji, Diu, and Laloë, 215-223.

[2]The amplitude of the wave function at a point squared is equal to the probability per unit volume of finding the corresponding particle there.

here, the quantum system is deterministic. All that is claimed so far is that instead of describing a tennis ball by specifying where it is and how it moves, we choose to look at the wave function (pink elephant) associated with a wavicle and how it moves.

However, it has been noted in the discussion above, that the act of observation seems to disturb the system as to yield a different outcome (one may recall that when "blindfolds" were not used two spots were obtained from the experiment whereas when "blindfolds" were used one obtained an interference pattern). So the next three postulates are introduced to explain these *observational data.*

The Third Postulate of Quantum Mechanics

Any act of measurement performed on a "wavicle" is represented by a mathematical operator acting on the corresponding wave function. In other words, any act of measurement on a "wavicle" has a well-defined mathematical meaning.

The Fourth Postulate of Quantum Mechanics

If there are several possible results of the measurement, the particular wave function is a linear combination of the pure states[1] associated with these results.[2] The probability[3] of obtaining a particular

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[1]A pure state (for a measurement) is a wave function which yields a specific result when the measure is performed. For example, the pure state yielding "three" for a quantum dice, say $|3>$, has 100 % chance of yielding "three" when the dice is cast but has no chance of yielding anything else.

[2]A wave function can be decomposed into different sets of pure states. This is similar to the situation of a three-dimensional vector (an "arrow")

value when making a measurement is simply the component of decomposition squared. For example, if one throws a quantum die, the wave function, say $|\psi>$,[1] of the die is a combination of six pure states, say $|1>$, $|2>$, $|3>$, $|4>$, $|5>$, and $|6>$, each associated with different outcomes of die-throwing. If the dice is "fair," that is, normal, then each component is the square root of one-sixth, that is, $|\psi> = \sqrt{1/6}\,|1> + \sqrt{1/6}\,|2> + \sqrt{1/6}\,|3> + \sqrt{1/6}\,|4> + \sqrt{1/6}\,|5> + \sqrt{1/6}\,|6>$. But if the dice is "loaded," then the state associated with the favored outcome will have a higher value for the corresponding component of decomposition. (For example, if a dice is loaded so that the outcome will always be "two," then the component of the decomposition of the state associated with "two" will be one, whereas the rest of the components will be zero. In other words, $|\psi> = |2>$.)

The Fifth Postulate of Quantum Mechanics

When a measurement is made and a particular value obtained, the wave function right after the measurement is a "pure" state (or pure wave function) composed of only the state corresponding to the value obtained. In other words, when a measurement is made on a "particle," then the wave function, by the very process of measurement, collapses to a pure state. For example, for the quantum dice mentioned above, if the first throw resulted in "two," then the wave function right after the first throw is $|2>$. This is called

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being able to be described by several different coordinate systems. The particular set chosen depends on the kind of measurement taken. .

[3]It is assumed here and in the example which follows that the space part of the wave function has been integrated over.

[1]This "ket vector" (from the word 'bracket') is a standard notation for a wave function. One may read it as ψ or ket ψ.

the "collapse of the wave function." How and where this collapse occurs brings out endless philosophical discussions[1] as one will soon see.

Explanation of the Double-Slit Experiment

The real test for quantum mechanics is whether or not one can use the above postulates to explain the double-slit experiment. When a measurement is *not* performed as to which of the two slits the electron is passing through, then the wave function goes through the system as a superposition of two pure states,[2] thereby resulting in an interference pattern.[3] But if the measurement is made to determine which of the two slits the electron is passing through, then there is a collapse of the wave function due to the measurement process itself. There is no interference pattern because there is now one pure state instead of a superposition state.

Peculiarities of Quantum Mechanics

The picture emerging from quantum mechanics is disturbing and challenging especially for a mechanistic view of the universe (such as Newtonian physics) in several different aspects. Contrary to Newtonian physics, according to quantum physics, any measurement carried out on a system (a system may be anything from a single electron to many "wavicles"

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[1]This philosophical problem is called the "measurement problem."

[2]This situation is analogous to the "fair" die. Since the electron has equal probability of passing through slit #1 as that of passing through slit #2, one has to construct the wave function as a superposition of two states.

[3]It is standard knowledge in physics that a superposition of a specific type of wave function required in quantum mechanics (vectors in Hilbert space, to use the technical term) leads to an interference pattern. But if the superposition is no longer present, then one no longer has interference pattern. This has to do with the fact that the square of the wave function at a point in space is related to the probability of finding the "wavicle" there.

interacting with a complicated experimental apparatus) disturbs the system and the *way* it disturbs is related to the result of the measurement. In Newtonian physics, if one knows the initial position and velocity of an object, whether or not one makes an observation on the object during flight does not make any difference to the outcome. After all, people's common belief about science indicates that science must be objective. If one throws a ball from the same position with the same velocity, one would not expect the ball to land at a different site just because one chose to blindfold oneself *after* the ball is already thrown. Or just because one decides to watch (not cheer) a football game, one does not expect to influence the outcome of the game itself. But in quantum physics, any measurement introduces a change in a fundamental way such that it becomes a different system altogether. Even if one chooses to observe, for example, instead of choosing not to observe, the very act of observation alters what one wants to observe.

Another interesting feature of quantum physics is that at this level even if one knows everything knowable within the theory itself, it is not usually enough to predict exactly what will happen.[1] Ordinarily, one at best knows the probabilities of various outcomes.[2] In Newtonian physics if one performs an experiment under identical conditions, exactly the same result is obtained every time. Therefore, not being able to predict the outcome exactly, in the case of dice-throwing for example, is an indication that there is some missing information. If one obtains the value of the elasticity of the dice and

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[1]An exception occurs when a wave function is in a pure state (right after a measurement is taken for example). Then the probability of obtaining the associated value is one, that is, we know what will be the outcome exactly. But generally a wave function is a combination of different states.

[2]One may recall the example of the quantum die; only the probabilities of various outcomes are known.

the table, the angle the dice hits the table, etc., it is *theoretically* possible, even if practically cumbersome, to predict exactly what number will turn up. In classical physics probability is a mere convenience and there is no theoretical reason why exact predictions cannot be obtained. If there is uncertainty, it is an indication that there is missing information somewhere. In quantum physics, there is a *theoretical* limitation in one's ability to predict. Probability is an intrinsic part of the theory itself.

CHAPTER III

INTERPRETATION OF QUANTUM MECHANICS[1]

Diversity of Interpretation

Relatively speaking, there were no philosophical controversies regarding Newtonian mechanics. Mass, force, etc., had a natural interpretation which can be easily reconciled with common sense. But from its very beginning, there has never been a *universally* accepted interpretation of quantum mechanics. Murray Gell-Mann observes,

> All of modern physics is governed by that magnificent and thoroughly confusing discipline called quantum mechanics. . . . It has survived all tests and there is no reason to believe that there is any flaw in it. . . . We all know how to use it and how to apply it to problems; and so we have learned to live with the fact that nobody understands it.[2]

In other words, there is no controversy when it comes to *using* quantum mechanics; but there is no agreement as to what the theory means.

It is, therefore, much more important when discussing quantum mechanics to consider various interpretations of quantum mechanics. That theory and its interpretation are inseparable is a truism. But it becomes

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[1]The following books contain concise overviews of various interpretations: Nick Herbert, Quantum Reality: Beyond the New Physics; Ronald C. Pine, Science and the Human Prospect. One book with some mathematics is, Edward Gettys, Frederick J. Keller, and Malcolm J. Skove, Physics: Classical and Modern (New York: McGraw-Hill Book Company, 1989). The classification scheme in this paper for various schools will follow closely the one used by Herbert.

[2]Murray Gell-Mann, quoted in Pine, 218.

explicitly necessary, when it comes to quantum mechanics, to consider the theory together with its variegated interpretations.

Certainly, the situation is much more complicated in the case of quantum mechanics than the case of Newtonian physics because of the many interpretations of the former. J. C. Polkinghorne compares this situation to that of having a beautiful palace without being certain about its foundation, whether it is on bedrock or sand.[1] The problem lies in the simple fact that its original interpretation seemed so absurd that many had difficulty accepting it. People seem to have difficulty accepting what does not appear to make sense. But one should take the warning of Richard Feynman to heart: "The 'paradox' is only a conflict between reality and your feeling of what reality 'ought to be.'"[2]

There is a diverse body of interpretations regarding the meaning of quantum physics. Several of these are mentioned briefly.

The Copenhagen Interpretation

The Copenhagen interpretation was the original interpretation of quantum mechanics and this view, and several variations of this interpretation, are held by the majority of physicists. This interpretation, therefore, is the "orthodox" interpretation. According to one major proponent of this school there is only one interpretation of quantum mechanics, namely the Copenhagen interpretation, since physical theory consists of the

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[1]J. C. Polkinghorne, The Quantum World (London: Longman Group, 1984), 1.

[2]Richard Feynman, quoted in Pine, 221.

formalism of the model and the (original) meanings attached to the symbols.[1] According to this interpretation quantum mechanics describes neither the micro-world nor the ordinary world; it describes the relationship between the two.[2] This school insists that one's ordinary concepts are not applicable to the quantum system. One of the main architects, Werner Heisenberg, attributed this to the inadequacies of the language formed by ordinary experiences. He said,

> The root of the difficulty is the fact that our language is formed from our continuous exchange with the outer world. We are a part of this world, and that we have a language is a primary fact of our life. This language is made so that in daily life we get along with the world; it cannot be made so that, in such extreme situations as atomic physics, or distant stars, it is equally suited. This would be asking too much.[3]

To insist that quantum systems[4] behave like ordinary macroscopic systems is a unwarranted extrapolation into a region of which we have no direct experience. According to Heisenberg, what we observe in our experiments is not nature itself but nature exposed to our methods of questioning it.[5]

In addition, the paradoxes generated by quantum mechanics are nature's way of telling us that we need mutually contradicting sets of systems

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[1]Paul Buckley and F. David Peat, A Question of Physics: Conversations in Physics and Biology (Toronto: University of Toronto Press, 1979), 19.

[2]Herbert, 161.

[3]Buckley and Peat, 9.

[4]"Quantum systems," according to this school of interpretation, refer to the microscopic world, the world of protons, electrons, etc. Some schools of interpretation propose that everything is quantum mechanical, including the world of desk, chair, etc.

[5]Pine, 226.

to understand nature. For instance, in order to understand the behavior of an electron, one has to use two contradictory pictures: the wave picture and the particle picture. This idea is called complementarity.

The Copenhagen interpretation is also anti-reductionistic in that a picture in biology may be just another picture,[1] not necessarily reducible to physics.[2]

As to the measurement problem, the Copenhagen interpretation says that the collapse of the wave function occurs in measuring devices. Reality, according to this view, is created by the act of observation. Physicist John Wheeler says, "the old word *observer* simply has to be crossed off the books, and we must put in the new word *participator*. In this way we've come to realize that the universe is a participatory universe."[3]

This school is anti-realist in that it denies any deeper underlying "quantum reality" beyond what can be measured experimentally. In other words, there is no reality in the absence of an observation. According to the Copenhagen interpretation, electrons, protons, etc., are mere theoretical constructs.[4] According to Heisenberg, the idea of "fundamental reality" itself

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[1]This is contrary to the traditional view which held that ultimately biology, chemistry, etc., is reducible to physics. In other words, everything in biology, chemistry, and other sciences can be explained, at least in theory, using physics.

[2]Ibid., 226-227.

[3]Buckley and Peat, 55.

[4]For an interesting discussion of this school, see Herbert, 16-17, 158-168.

arises from unwarranted extrapolation of our ordinary experience into the quantum realm.[1]

Niels Bohr, one of the most famous proponents of this school, said: "There is no quantum world, there is only an abstract quantum description."[2] Some physicists do not even believe in the ontic nature of "things" like electrons and protons. For them, this does not mean that physics is subjective. It simply means that physics is objectless.[3]

Physicist David Mermin summarizes the interpretation this way: "We now know that the moon is demonstrably not there when nobody looks."[4]

Neo-Realism

Proponents of neo-realism include David Böhm,[5] Albert Einstein, Max Plank, Louis de Broglie, and Erwin Schrödinger. They do admit the successfulness of quantum mechanics in explaining observational data. But they reject the sharp dichotomy between the ordinary world and the quantum world that the Copenhagen interpretation makes. This school holds that everything is ordinary and the puzzling aspects of quantum mechanics are due to the incompleteness of the theory.[6] But the number of experimental evidences supporting quantum mechanics is increasing. In particular, the

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[1]Buckley and Peat, 9.

[2]Niels Bohr, quoted in Herbert, 17.

[3]Herbert, 162.

[4]David Mermin, quoted in Herbert, 17.

[5]David Böhm has proposed more than one interpretation of quantum mechanics.

[6]Herbert, 22-24.

Aspect experiment seems to support quantum mechanics and affirms it as complete.[1] J. S. Bell showed that if electrons, etc., are ordinary objects then superluminal (faster-than-light) waves are unavoidable.[2] This spells more trouble, since it undermines causality as we understand it.[3]

Reality as an Undivided Wholeness

There are several varieties in the school of reality as an undivided wholeness, such as Wheeler's wormhole picture,[4] Penrose's twistor theory,[5] and the mystical brand of Capra[6] and Zukav.[7] But here Böhm's picture is mainly considered. This school accepts an observer-created reality, thereby dissolving the boundary between subject and object. According to this view, there is no causal hook-up.[8] Everything in the universe is connected undiminished with everything else. Whereas in classical physics, object, equipment, and observing human being are all separate, in "quantum

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[1]For an interesting discussion on this, see Pine, 233-235.

[2]Herbert, 244.

[3]This can be understood easily via relativistic spacetime diagram. Those who are interested may refer to any introductory book on special relativity. (See, for example, Delo E. Mook and Thomas Vargish, Inside Relativity [Princeton, NJ: Princeton University Press, 1987], 88-95.)

[4]F. David Peat, Einstein's Moon: Bell's Theorem and the Curious Quest for Quantum Reality (Chicago: Contemporary Books, 1990), 135-140.

[5]Ibid., 140-142.

[6]Fritjof Capra, The Tao of Physics: An Exploration of the Parallels Between Modern Physics and Eastern Mysticism (Boulder, CO: Shambhala Publications, 1983).

[7]Gary Zukav, The Dancing Wu Li Masters: An Overview of the New Physics (New York: Bantam Books, 1979).

[8]Herbert, 19.

mechanics one sees that the process by which these different things would interact cannot itself be analyzed in detail. It is whole and indivisible."[1] With the idea of non-local "in-form-ation," the proposed basic paradigm of the universe is that of an "organism of great subtlety."[2]

It is also interesting to note that many interpreters of quantum mechanics are quite friendly toward religion, in contrast to their Newtonian predecessors. David Böhm considers religion and science to be essentially the same in their attempts to obtain wholeness, even though they both have been unsuccessful.[3] According to him, quantum mechanics possibly implies such a wholeness, not only between an individual and his/her environment, but also between inanimate objects. The whole simply "cannot be analyzed into separate parts with preassigned interactions."[4] Böhm sees, in this new physics, a chance to wholeness. He claims that it "is not incompatible with a religious approach. . . . On the contrary, it is more compatible with this [religion] than it is with a mechanistic approach. So at least fragmentation between science and religion may perhaps thus be capable of being healed."[5]

Quantum Logic

Another group of people believes that the key to the puzzle lies in discovering a new logical system different from the ordinary one. In other

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[1]Buckley and Peat, 132.

[2]Peat, 155.

[3]David Böhm, "Fragmentation and Wholeness in Religion and in Science," Zygon 20 (1985): 125-127.

[4]Ibid., 128

[5]Ibid., 130.

words, if our logical system is to survive and continue to have relevance to reality, it needs to go through a major revision. So far there does not seem to be a completely successful revision.[1]

Consciousness-Created Reality

The major proponent of consciousness-created reality is John von Neumann. This interpretation is similar to the Copenhagen interpretation. But this view says that everything is quantum mechanical, including ordinary objects. The major difference is that this view states that only an apparatus endowed with consciousness is privileged to create reality, not any measuring device.[2] According to von Neumann, only the presence of consciousness can help to solve the "measurement problem."[3] So, in effect, if there are no conscious beings around and only a detector, say a telescope, is operating, reality is still being created by the detector according to the Copenhagen interpretation. But von Neumann would insist that there is no reality since without consciousness there is no reality created.

The Many-Worlds Interpretation

When there are several different outcomes possible, then all of them actually do occur. But each outcome occurs in its own universe. So in effect

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[1]For a more detailed discussion on quantum logic, see Herbert, 177-189.

[2]For a discussion regarding such devices, see John von Neumann, Theory of Self-Reproducing Automata (Urbana, IL: University of Illinois Press, 1966); A. E. Wilder-Smith, The Scientific Alternative to Neo-Darwinian Evolutionary Theory (Costa Mesa, CA: TWFT Publishers, 1987).

[3]John von Neumann, Mathematical Foundations of Quantum Mechanics, Investigations in Physics, no. 2, trans. Robert T. Beyer (Princeton, NJ: Princeton University Press, 1955), 417-445; for a brief discussion, see Herbert, 189-190.

the universe splits into as many distinct universes as there are possible outcomes when a measurement is taken.[1] This view avoids the measurement problem by saying that there is no collapse of the wave function. But this is done by sacrificing the ordinary way of looking at the universe.

It is interesting to note that whereas not even one world is possible according to the Copenhagen interpretation, according to the many-worlds view, numerous worlds are possible.[2]

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[1]For a more detailed discussion, see Bryce De Witt and R. Neill Graham, The Many-Worlds Interpretation of Quantum Mechanics (Princeton, NJ: Princeton University Press, 1973).

[2]My own interpretation of quantum mechanics and my reaction to other interpretations have been deliberately left out because the conclusions I draw in this thesis do not depend on them.

CHAPTER IV

IMPLICATIONS FOR CHRISTIAN THEOLOGY

A Call for Caution

It is tempting, based on the solid success of quantum mechanics, to formulate a "quantum theology." But one should be cautious since any successful theory, such as quantum mechanics, may face a fate similar to its predecessors "of being vanquished by another as long as science does not succeed in emancipating from all history."[1] Various attempts to achieve this emancipation and failures of such attempts have been discussed elegantly by Stephen Toulmin.[2] He further noted that,

> Twice already [the Aristotelian paradigm and the Newtonian-Cartesian paradigm] theologians have committed themselves enthusiastically to the detailed ideas of particular systems of scientific theory. . . And, when radical changes took place in the natural sciences, they were unprepared to deal with them.[3]

Therefore, it seems wise to avoid generalizing too much from the current model of science. We should heed the warning of Matthew Lamb not to yield one's heart to the "tempting myths of success" by evaluating "their success as powerful enough to answer adequately all further relevant

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[1]Rüdiger Bubner, "Paradigm Change: Some Continental Perspectives," in Paradigm Change in Theology: A Proposal for Discussion, ed. Hans Küng and David Tracy, trans. Margaret Köhl (New York: Crossroad Publishing Company, 1991), 252.

[2]Toulmin, 234-236.

[3]Ibid., 237.

questions or criticisms."[1] It is especially important for theologians not to commit themselves to a particular scientific model and its details. It will be better, according to Stephen Toulmin,

> If theologians heed the sceptics, free themselves from the seduction of 'new paradigms', and become frankly reconciled to being (in that sense) 'paradigmless'. It will be better if they distance themselves from the ideas of science rather than embrace them too systematically and uncritically.[2]

General Implication

So what are the implications of quantum mechanics for theology? One thing that seems clear is that even if quantum mechanics is replaced by another theory, that theory can never return to the classical picture of reality.[3] In particular, Bell's theorem, which according to Peat is "an elegant way of tricking nature into revealing one of its secrets," seems to indicate that the universe is "stranger than anyone could have imagined."[4] Therefore, it seems wise for theologians to avoid returning to the simple mechanistic picture of reality.

Whenever something is done one way or generally accepted to be true for a long time, there tends to accumulate a bag of myths concerning it. Science is no exception. Apparent success makes it easier for science to accumulate much dross over the years. John Wright correctly observes that

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[1]Matthew L. Lamb, "The Dialectics of Theory and Praxis Within Paradigm Analysis," in Paradigm Change in Theology: A Proposal for Discussion, ed. Hans Küng and David Tracy, trans. Margaret Köhl (New York: Crossroad Publishing Company, 1991) , 78.

[2]Toulmin, 237.

[3]Peat, 116.

[4]Ibid., 2.

because of earlier victories of science over philosophy and theology, "science tended to induce an attitude of omnipotence in the scientific mind. Whatever could not be known by science was either unknowable or not worth knowing."[1] In particular, it was the "awesome regularity of the mechanical universe as emphasized by Isaac Newton" that led to later intellectual development including deism.[2] Also determinism inherent in Newtonian physics influenced fields such as behavioral psychology. It is "ironical to see the result of an *idee fixee*, discarded from the world of physics, held to religiously in a field where there was little reason to adopt it in the first place."[3] Quantum mechanics proves useful in identifying certain non-essential aspects of science which have been considered to be essential for a long time under the spell of success and which many theologians and philosophers *still* follow. This "demythologization" is extremely important for theologians who want to dialogue with scientists.

The situation is somewhat analogous to the American political system in which the two-party system is dominant. It is easy for some to believe, in the light of many attempted failures of third-party candidates in becoming elected, that the two-party system is an inherent part of the political system in a country like the U.S. But now suppose that an independent candidate *has* won the election by a landslide. Even if he or she loses the election next time around, the myth of the two-party system as a necessary ingredient of the American political system is shattered

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[1]John H. Wright, "Theology, Philosophy, and the Natural Sciences," Theological Studies 52 (1991): 658.

[2]Russell, 626.

[3]Albert E. Smith, "Does God Play at Dice?" Origins 4(1977): 39-40.

irreparably. Similarly, even if quantum mechanics is overthrown by a subsequent development, some myths about science can no longer be accepted without question.

Tentative Nature of Science

First, quantum mechanics has brought home the tentative nature of science. This is easy to understand when one looks at the structure of science itself. But since the Newtonian paradigm had been successful for such a long time, and moreover all corrections seemed to come in the forms of modification, relatively speaking, rather than in terms of revolution, a myth is created that science is a discipline concerned with discovery. This trend may even be traced from the time of Plato until the twentieth century in having essentially the same framework concerning reality. According to Stephen Toulmin, this comprises a permanent system with "a fixed and unchanging structure" that is ahistorical.[1] Carl von Weizsäcker terms this framework as seeing with a "divine eye" and states that quantum theory makes this untenable.[2] With quantum mechanics, the historicization of science comes into the forefront of philosophy of science.[3]

Not only the implications of the theory of quantum mechanics, but also the fact that the theory itself supplanted a remarkably successful physical model (Newtonian physics) accentuates the reality that *any* accepted model in science, no matter how successful, can be superceded by

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[1]Toulmin, 234-235.

[2]Buckley and Peat, 70.

[3]Even though Stephen Toulmin (see the article above) attributes this to Thomas Kuhn among others, I think that being trained in physics where quantum mechanics is the basic language of research helped Kuhn shape his view.

another model. Theologians should be careful, therefore, not to wed too much of their theological system with contemporary science if they do not want their system to become obsolete. This holds true even when the success of a model becomes enticing, as the history of science has shown.

Reductionism

Reductionism, too, can no longer be accepted as an essential part of science. Wright properly raised this question:

> Can we assume without argument that whatever is is mass/energy in space/time, built up into atomic, molecular, biological, psychological, and social relationships? Or does the world have other ways of being known and explained that are neglected by this approach?[1]

Many will answer affirmatively that quantum mechanics *is* one non-reductionistic model which is perhaps the most successful one in the history of science in terms of experimental confirmation. Heisenberg made the following interesting remark:

> Even if quarks [reductionistic elementary particles] should be found (and I do not believe that they will be), they will not be more elementary than other particles, since a quark could be considered as consisting of two quarks and one anti-quark, and so on. I think we have learned from experiments that by getting to smaller and smaller units, we do not come to fundamental units, or indivisible units, but we do come to a point where division has no meaning."[2]

It is not necessary to go overboard and say reality *is* holistic since quantum mechanics seems to be, because even quantum mechanics is vulnerable of being overthrown. But it is at least clear that one can do good science without being reductionistic in one's approach. For theologians, this

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[1]Wright, 659.

[2]Buckley and Peat, 15.

means that one may adopt a reductionistic theological system but only as one's preference, not as a scientifically mandated system.

Determinism

Determinism no longer carries the weight it used to carry, especially under the Newtonian paradigm. That quantum mechanics is not deterministic is a truism. For example, one can only predict probabilistically what the behavior of an electron will be. In contrast, it was possible to give the exact prediction of the behavior of a given particle in Newtonian physics. The fact that quantum mechanics has reigned supreme for quite some time now militates against the position that science *has to be* deterministic. Theologians should not think, therefore, that to be scientific one has to have a deterministic (closed) system.

Logic

Logic (as we understand it today) no longer seems to be absolute. From all the paradoxes it is reasonable to conclude that our logical system needs to go through some modifications, maybe even as dramatic as the revolution brought on by quantum physics itself. This has profound implications with regard to rationality in general. According to Lamb, rationality can no longer be defined in a purely mathematical sense. He further states that "the deductivist ideals of theory *qua* theory providing coherent and complete criteria for rationality are gone. . . . Rationality cannot be identified with ideals appealing to non-existent and impossible complete and consistent foundations in theory *qua* theory."[1] This may serve

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[1]Lamb, 70-71.

as a warning to theologians not to wed too much of their theology with the current model of logic itself.

Subject-Object Dichotomy

Subject-object dichotomy no longer seems to be a necessary part of science. According to Lamb,

> An underlying assumption which fostered this dichotomy between objectivity and subjectivity was a desire to reconstruct the methods of the natural sciences into formally logical, ahistorical procedures of 'pure objectivity' or 'pure reason' cut off from any trace of subjectivity. . . . It seems to me that there is an emerging consensus about the illusory character of this underlying presupposition of a logically pure objectivism in natural science."[1]

We have traditionally accepted this dichotomy and insisted that our science, and any other areas that aspire to be scientific, be 'objective.' But what the structure of science requires is that the predictions be testable, not necessarily objective. Moreover, quantum mechanics shows that the separation of objectivity from subjectivity is not meaningful; this is shown clearly in observer-dependent phenomena. The participatory universe resulting from quantum mechanics, more than the mechanistic universe, has greater chance of reconciliation with religion, in which "knowledge is possible only by participation."[2]

Reality of the Objects in a Scientific Model

Perhaps most importantly, just because a scientific model is successful one cannot conclude that the "objects" in the model are real entities. There is no guarantee of the reality of those objects either in the

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[1]Ibid., 69-70.

[2]Ian G. Barbour, Religion in an Age of Science, The Gifford Lectures, vol. 1 (New York: HarperCollins Publishers, 1990), 121.

method of science or the practice of science. The only thing science requires is that the proposed model should work. Theologians should be careful not to wage war against science, assuming that a good scientific model is *the* true description of the reality. Just because the Big Bang Theory is successful scientifically, it does not follow that this was how it actually *did* happen, even though the theory itself gives a good theoretical framework to understand much of the observational data at hand.

Assessment

What are some of the theological implications for these negatives? It is important to remember that realizing the limitations of science is not a weakness but a strength, a true sign of maturing. That this greater epistemological caution and humility is fostered by quantum mechanics is evident by the attitudes of various scientists. Nevill Mott frankly admits that, "I am far from believing that science will ever give us the answers to all our questions."[1] Many physicists are even open to the idea of God, be it to answer the origin question,[2] or to address the need for God in the universe and one's own life.[3] Only after the myths of science are broken can a true reconciliation occur between science and theology.

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[1]Nevill Mott, "Science Will Never Give Us the Answers to All Our Questions," in Cosmos, Bios, Theos: Scientists Reflect on Science, God and the Origins of the Universe, Life, and *Homo sapiens*, ed. Henry Margenau and Roy Abraham Varghese (La Salle, IL: Open Court, 1992), 65.

[2]Geoffrey F. Chew, "Appeal to God May Be Required to Answer the Origin Question," in Cosmos, Bios, Theos: Scientists Reflect on Science, God and the Origins of the Universe, Life, and *Homo sapiens*, ed. Henry Margenau and Roy Abraham Varghese (La Salle, IL: Open Court, 1992), 36.

[3]Arthur L. Schawlow, "One Must Ask Why and Not Just How," in Cosmos, Bios, Theos: Scientists Reflect on Science, God and the Origins of

Attempts to Draw Metaphysical Implications

It is important to mention that there have been many attempts to draw some metaphysical implications of quantum mechanics. Perhaps the most famous of these is by Fritjof Capra who attempted to show similarities between quantum mechanics and Eastern religions.[1] But it is my opinion that this attempt rests on shaky ground as discussed above.

Similarly, monism, dualism, and pluralism with regard to the relation between science and religion appear to be too speculative.[2] One may adopt any of these positions via theological arguments, but without claiming "scientific" status.

After looking at modern physics, Paul Davies stated that "it would be foolish to deny that many of the traditional religious ideas about God, man and the nature of the universe have been swept away by the new physics."[3] But this will be reasonable if the current quantum model is permanent, and also if it truly *does* describe the reality. But according to the conclusion of this thesis, neither of these is *necessarily* so. Therefore, one can say Paul Davies' conclusion does not logically follow from quantum mechanics or any other scientific model. It is his own speculation.

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the Universe, Life, and *Homo sapiens*, ed. Henry Margenau and Roy Abraham Varghese (La Salle, IL: Open Court, 1992), 107.

[1]Capra, The Tao of Physics: An Exploration of the Parallels Between Modern Physics and Eastern Mysticism.

[2]Erwin Hiebert, "Modern Physics and Christian Faith," in God and Nature: Historical Essays on the Encounter between Christianity and Science, ed. David Lindberg and Ronald Numbers (Berkeley, CA: University of California Press, 1986), 434-443.

[3]Paul Davies, God and the New Physics (New York: Simon and Schuster, 1983), 229.

A more cautious approach was adopted by Willem Drees. He observed the following:

> The presence of metaphysical ideas as partly guiding research is possible due to the underdetermination of the theories by the present data. Such metaphysical differences about the nature of time or between the possibilities and the actualized realities seem to be persistent. It might be that one of the programs would become the new scientific consensus, are unmatched by the others. But even then, there could be different interpretations as long as people hold different metaphysical convictions. Differences in formalism have disappeared in standard quantum theory, but it still has its variety of interpretations.[1]

Yet, Drees imposed an unnecessary restriction on theology when he wrote, "*Creatio ex nihilo* should not be understood as referring to an event of origination, for that is not in line with contemporary cosmology."[2] The same criticism used against Paul Davies applies here also.

Ian Barbour tried to draw some metaphysical implications. His three metaphysical implications are:

1. Temporality and historicity (Time as a fundamental element of the reality)

2. Chance and Law (quantum indeterminacy--unpredictable novelty)

3. Wholeness and emergence (holistic view of the reality).[3]

Barbour's conclusions seem very interesting and are quite suggestive of a biblical view of the reality. But to take these too seriously is to commit the same mistakes that "Newtonian" theologians have made in the past.

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[1]Willem B. Drees, Beyond the Big Bang: Quantum Cosmologies and God (La Salle, IL: Open Court Pub. Co., 1990), 67.

[2]Ibid., 203.

[3]Barbour, 123-124.

Conclusion

Fascination with what quantum mechanics might mean is not an exclusive domain of scholars. Robert Wright, in a recent popular magazine article, wrote that twentieth-century science has provided a fertile ground for "bona fide theological speculation: speculation about whether the universe is a product of intelligent design, whether the human experience is part of some unfolding purpose, whether we were in any sense meant to be here."[1] He further observed that respect for metaphysics and respect for the unknowable are some of the results of the new science. He concluded his article as follows:

> 100 years ago, with Darwin having shown how a long chain of tiny accidents had happened to yield the human species, with metaphysics in retreat and the clockwork laws of classical physics ascendant, and with the universe's deft conduciveness to life as yet unfathomed, one might have thought "the theological possibility" an unlikely survivor of the next century's science. That it should survive in such robust form would have seemed less likely still. This holiday season the unconventionally religious can join the conventionally religious in counting their blessings.[2]

But before one jumps to facile conclusions, care must be taken not to draw too much from the currently successful scientific model. In my opinion, it was *not* the details of quantum mechanics which gave rise to the above shift in thinking; it was, rather, the elimination of the various myths inimical to religion that gave rise to this shift. By eliminating the myths, quantum mechanics helped to envisage what Willem Drees called a "metaphysical conceptual space." Therefore, the main benefit of quantum mechanics for theologians is to clear away the myths concerning science, not to construct a

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[1]Robert Wright, "Science, God and Man," Time, December 28, 1992, 40.

[2]Ibid., 44.

quantum theology.[1]

[1]The focus of this thesis is almost exclusively epistemological. That is why so much effort is taken not to say any more than warranted. On this level, it seems best not to appeal to various details of current scientific theories, except for "demythologization," no matter how successful the theories may appear to be. But it is not my intention to say, via negativities, that one *cannot* use the quantum model analogically or metaphorically in trying to understand the Reality. That one can do that follows from the unity of God, even though our understanding of science *and* theology is imperfect. It my conviction that quantum mechanics has brought the epistemological framework closer to a "biblical" epistemology than has the Newtonian model. But this issue is beyond the scope of this thesis.

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