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THE NOTION OF REALITY
IN THE THOUGHT OF SIR ARTHUR STANLEY EDDINGTON:
A STUDY IN SCIENCE AND RELIGION

Thesis Submitted to the Faculty of Graduate Studies

of the University of Manitoba

in Partial Fulfillment of the Requirements for

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THE NOTION OF REALITY IN THE THOUGHT OF SIR ARTHUR STANLEY EDDINGTON: A STUDY IN SCIENCE AND RELIGION.

by

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List of Abbreviations

The following is a list of frequently cited works that are referred to in the Endnotes in abbreviated form:

NPW Eddington, A. S. *The Nature of the Physical World.* New York: Macmillan Company, 1929

PPS Eddington, A. S. *The Philosophy of Physical Science.* Ann Arbor: University of Michigan Press, 1958; Cambridge: University Press, 1939

ST&G Eddington, A. S. *Space, Time and Gravitation: An outline of the general relativity theory.* Cambridge: University Press, 1921

DPS Eddington, A. S. "The Domain of Physical Science," in *Science, Religion and Reality.* Edited by Joseph Needham. New York: George Braziller, Inc., 1955

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INTRODUCTION

A. Vibert Douglas, in his insightful study *The Life of Arthur Stanley Eddington*, has said of Eddington, that "his writings, more than any other influence at that time, aroused a fresh realisation of the reality and importance of spiritual values."[1] It is the aim of this thesis to reawaken interest in Eddington's writings on the nature of reality, and the interaction between the methods of science and religion, so that the "realisation of the reality and importance of spiritual values" might once again be aroused.

Eddington originally caught the interest of scientists, philosophers, and lay persons throughout the world by writing--in a stimulating and provocative fashion--about the implications of Einstein's theories of relativity for philosophy and religion. As

> a great scientist entering another field, he used his scientific knowledge to plough up the ground, and provided the professional philosophers with the opportunity of refreshing themselves by harrowing his furrows. . . .[2]

The response to Eddington was varied. Amongst scientists he was admired as a devoutly religious man, and as a great thinker--the pioneer of astrophysics. By lay people and clergy he was heralded as deducing religion from physics--a conclusion which Eddington

strongly opposed. Philosophers' reaction to Eddington's philosophy ran "the gamut from mirth to disparagement."[3]

Eddington's concepts deserve to be re-examined. While early critics of Eddington refused--in an almost parochial fashion--to consider this new *Weltanschauung* that science was proposing, the pop market is flooded today with books claiming that the "new physics" in some way proves the existence of God or cosmic consciousness. Eddington acknowledged that

> It is probably true that the recent changes of scientific thought remove some of the obstacles to a reconciliation of religion with science; but this must be carefully distinguished from any proposal to base religion on scientific discovery. For my own part I am wholly opposed to any such attempt.[4]

Instead, Eddington attempted to show that physics was revealing only one aspect of nature, namely the metrical one, and that there are other approaches to ultimate reality. Where the two 'join' is when science has gone as far as it can and leaves open to mind the possibility of encountering something beyond the realm of exact science. Eddington succinctly states that his

> thesis has been that the recent tendencies of scientific thought lead to the belief that mind is a greater instrument than was formerly recognised in prescribing the nature and laws of the external world as studied in physical science; that in exploring his own territory the physicist comes up against the influence of that wider reality which he cannot altogether shut out; and that by its selection of values the mind may indeed be said to have created its physical environment.[5]

Without simplistically unifying either objective

science or experiential religion, Eddington discusses scientific and spiritual realities without disparaging either, and this alone makes his work worth re-evaluating.

As this thesis discusses Eddington's views on the nature of reality, care is taken to place his thought in context. Previous studies of Eddington's thought have generally represented him as the only scientist who appreciated the changes that the relativity theory implied; by comparing Eddington's views with those of his contemporaries, it becomes clear that he is in fact representative of the philosopher-scientists of his generation.

Finally, to understand Eddington it is essential to see him in his proper religious context. It will be shown that his Quaker background was influential in forming his philosophy of physical science.

This inquiry into Eddington's thought utilizes materials readily available and discussed by other writers in the field, and is neither exhaustive in its scope nor entirely original in its conception. Each chapter contains elements of various researchers' work, but the emphasis throughout is on Eddington's own writings.

While there is nothing particularly unique about Eddington that comes out in any one chapter of this

study, what could be considered different about this thesis is the union of different approaches that have been taken to Eddington. Of the four most extensive analyses of Eddington extant, that of J. G. Crowther is perhaps widest in scope, encompassing elements of Eddington as scientist, philosopher and Quaker, but without going into much detail. As an analysis of Eddington's philosophy of physical science, John W. Yolton's work is invaluable. Yolton clearly delineates Eddington's philosophy, and makes it evident that Eddington held to both a phenomenological and to a realist ontology. Yet in his central chapter on Eddington's concept of reality, he is unable to see how the two opposing views can be used harmoniously by Eddington because he fails to appreciate the importance of Eddington's Quakerism. In *The Life of Arthur Stanely Eddington* Douglas certainly highlights Eddington's Quaker background, but the nature of a biography is not such that it would pursue the paradoxes in Eddington's philosophy and see how important this element of Eddington's character was. Perhaps the best work on Eddington is Johannes Witt-Hansen's *Exposition and Critique of the Conceptions of Eddington Concerning the Philosophy of Physical Science.* Witt-Hansen carefully and clearly analyzes Eddington's philosophy. Most noteworthy are the extensive comparisons of Eddington's

ideas with those of Kant; their ideas are not exactly the same, but similar enough to allow Kant's more reasoned expositions to clarify what Eddington was getting at.

The aim of the present thesis is to highlight some elements of Eddington's thought, with emphasis placed on his concept of reality, and on the placement of Eddington's views in their proper intellectual milieu. While critical use is made of previous works on Eddington, references are made primarily to Eddington in order to allow his words to speak for themselves.

Chapter one contains a short biography, and a discussion of Eddington's intellectual milieu, giving examples of contemporary views on reality, and on the relation between science, philosophy, and religion. Chapter two is an overview of Eddington's statements about reality, dealing with the question of how the mind constructs reality and with various kinds of reality--physical, underlying, and spiritual. Chapter three is a look at Eddington's views on the importance of consciousness and the limits of what science can tell us about reality. Chapter four deals with Eddington as a Quaker, highlighting views expressed in his writings that indicate his appreciation of the mystical nature of ultimate reality.

Format and method of citation are based on Kate L. Turabian, *A Manual for Writers*. 5th ed. (Chicago: UP, 1987).

CHAPTER ONE

Eddington and his Contemporaries

> I maintain that cosmic religious feeling is the strongest and noblest incitement to scientific research.[1]
>
> Einstein

> It is still, I think, an unfamiliar idea among scientists that scientific philosophy should have any relation to scientific practice.[2]
>
> Eddington

In this chapter I want to place Eddington and his ideas within his scientific milieu. This will involve a brief account of his life, and then an overview of his views compared to those of his contemporaries. In describing the world-view of Eddington's time it is apparent that some Kantian ideas pervade the scientific community, and that there is widespread recognition of the mental, constructed nature of physical reality.[3]

Biography

A. S. Eddington was born in Kendal, England on the 28th of December 1882.[4] His father, who had been a

Quaker schoolmaster, died of typhoid when Arthur was but two years old. Arthur's mother, Sarah Ann Shout, came from a long line of Yorkshire Quakers. Mother and son moved to Somerset, settling at Weston-super-mare. His mother was apparently a determined woman, who though poor, struggled to maintain her middle-class status. Her character is reflected in Eddington's quietly determined pursuit of integrity in science.

Eddington's interest in science developed despite the impoverishment of his family. His mother was able to send him to private school, where he cultivated an interest in Mathematics and Astronomy. It is said that he knew the 24X24 table before he could read, and at the age of six was already fascinated by large numbers. He often attempted to count the stars, and at one point tried to count all the letters in the Bible (He got as far as the end of the Book of Genesis). Further, by the time he was ten he had observed much of the sky with a three inch telescope which he had borrowed from his headmaster, and it is evident that his interest in Astronomy never declined.

His interest in the sciences soon brought scholastic success; in December 1896 he obtained a first class in the Cambridge Junior Locals, with distinction in Mathematics. He was only thirteen at the time. In 1898 he won his first scholarship, allowing him to go to Owen

College, Manchester. While there he concentrated on physics and mathematics for a period of three years, receiving academic distinctions and scholarships along the way. He graduated with a first class Bachelor of Science degree in physics, and went on to study at Trinity College, Cambridge.

His success continued at Cambridge, where he won the distinction of Senior Wrangler after only two years of study, an unprecedented accomplishment.[5] The mathematics taught at Cambridge at this time stressed the application of physical models as a means of conveying insight into physical systems.[6] His familiarity with this technique allowed him to excel in clarifying difficult concepts in his books, consolidating ideas in simple examples. The Cambridge emphasis on modeling also encouraged the tedious process of the development and explication of scientific theories; Eddington's grasp of Einstein's Theory of Relativity and its consequent brilliant explication by him are further evidence of his comprehension of classical Cambridge mathematics.

J. G. Crowther commented that "Eddington was extraordinarily clever and a wonderful learner. . . . His Quaker self-sufficiency and perseverance, as well as his native intellectual ability, made him a confident and successful individualistic competitor."[7] After Cambridge, he went on to obtain a second Bachelor of

Science degree from London, and a Bachelor of Arts from Cambridge in 1905. Thereafter he remained at Cambridge, teaching and doing research until he received the invitation of Sir William Christie, the Royal Astronomer, to become Chief Assistant at the Royal Observatory, Greenwich, in 1906. In 1913, at the age of thirty, he was appointed Plumian Professor of Astronomy at Cambridge.

Eddington was at Greenwich from 1906 until 1913, and these were some of his most fruitful years. Besides doing much of the regular work of an astronomer, he had opportunity to sail to Malta in 1909 to determine the exact longitude of a geodetic station, and in 1912 to Brazil to observe his first total eclipse of the sun. During this time he also began publishing his works, became a fellow of the Royal Astronomical Society, and eventually its Secretary. By 1918 he had ceased to do any regular practical astronomy.[8]

Though we will not dwell here on his published mathematical treatises, the above summary of his quick rise to the distinguished post of Chief Assistant was the result of his remarkable mathematical breakthroughs and achievements. He was clearly a master of classical mathematics and physics.

Eddington was not only a master of mathematics, but also a superlative expositor. At his best, "Eddington

was a typical example of the British tradition in physical science, the combination of skill in mathematical problem-solving with a strong physical and engineering sense."[9] He used simile, fable and pun to great effect. He masterfully allowed scientific processes to speak for themselves; making them come alive to his audience. He had poetic feeling, and a sense of humor. He could wield his cognitive skills dexterously and attack the most difficult problems, providing solutions that were readily understood by a diverse audience.

He was one of the very few scientists of great distinction who could explain his and others' discoveries in clear and even entertaining language. Crowther suggests that the precision of Eddington's presentations comes not from a cultivated literary style, but from the clarity with which the ideas presented themselves to his mind.[10] In short, he was in his time not only "the greatest living astronomer,"[11] but also an inspired writer, an artist.[12]

Eddington's excellence in science and its exposition gave his ideas a great deal of exposure, yet he is best characterized as a quiet, internally focused thinker. He tended to speculate deeply, and was particularly adept at independently formulating theories from limited data.[13] He was fond of the Quaker practice of silence in worship,

and used silence also during his lectures, where he would often spend long moments in deep meditative silence pondering a problem, coming out of his reverie only when he had devised a clear solution. He evidenced a tendency to contemplation and independent intuitive thinking that was no doubt a part of his personality, but also reinforced by the intellectual and religious habits of the Quakers, who taught that truth could be obtained through direct and personal inspiration[14]

Eddington's Quaker beliefs affected not only his cognitive temperament, but also the direction of his career. It was his Quaker inspired pacifist stance which led to his having opportunity in war-time Britain to prepare for his famous observation of the bending of light in the solar eclipse of 1919.

The Quaker belief in the presence of God in all people tempered his attitude towards the enemies of Britain, the Germans, from whom had come the momentous announcement of relativity. This is evident in a candid letter on the "Future of International Science", where he writes that the

> indictment of a nation takes an entirely different aspect when applied to the individuals composing it. Think not of a symbolic German, but of your German friend Professor X, for instance--call him Hun, pirate, baby- killer, and try to work up a little fury. The attempt breaks down ludicrously.[15]

Eddington did not suffer from any prejudice against the Germans. This receptive attitude, in addition to his

being secretary of the Royal Astronomical Society, put him in a unique position to receive and appreciate the wartime news of Einstein's Theory of General Relativity; in contrast, other scientists staunchly refused to believe that anything worthwhile could come from Germany.[16] Eddington received a copy of Einstein's 1915 paper on the General Relativity Theory shortly after it was published, and because it was wartime, this was the only copy in England for some time. Eddington grasped its significance at once, and began to explain it to his colleagues, even though this took time away from his own research. He pointed out the paradoxes of relativity in his elegant style, leaving others wondering why they couldn't see it as clearly as he did.

Questions concerning the impact of Einstein's theory on philosophy and religion occupied much of Eddington's research. He received recognition of his accomplishments both by becoming one of the best known "authorities" on scientific matters in his day, and through many official honours and awards, which he humbly accepted.[17]

Eddington's Contemporaries

To comprehend the impact of Quakerism on Eddington's thought, a comparison with his contemporaries is invaluable; for when he is placed within the context of

his scientific community, it becomes clear that Eddington's views were not merely a variation on the theme of Neo-Kantian influence which was pervasive at this time, but something distinctly unique. At the same time, Eddington was also caught up in the spirit of the times, for when his notions of reality are compared to those of Einstein, Planck, Heisenberg, Sir James Jeans, and Schrödinger, it becomes apparent that these men also recognized the limits of scientific knowledge, and its implications for philosophy. More to the point, their views on reality and its *constructed* nature, on the need for philosophy in physics, and on the limits of science, are significantly similar.

The scientific milieu in which Eddington developed his epistemology of science was one in which Kantian notions were widespread; but belief in concrete objective reality had not yet been wholly abandoned. There was considerable tension between these two viewpoints, and most leading scientists felt compelled to voice their opinions on the nature of science and reality.

Max Planck, arguably *the* representative of German scientific thought at this time, reminds us of a statement--made by Einstein--that must be valid for all practicing physicists, namely that "you could not be a scientist if you did not know that the external world existed in reality, but that knowledge is not gained by

any process of reasoning. It is a direct perception. . . . a metaphysical belief."[18] Similarly, Planck himself said that there must be "an objectively existing real universe. . . . [an] outside world. . . . independent of man. . . something absolute."[19] Both Einstein and Planck believed in the actual existence of an "objective real world whose smallest parts exist objectively in the same sense as stones or trees exist, independently of whether or not we observe them."[20] Similarly, the British scientist Sir James Jeans claimed that the "material universe remains as substantial as ever it was, and this statement must, I think, remain true through all changes of scientific or philosophical thought."[21]

The external world exists. That is a basic presupposition for doing physics. It must be kept in mind that all credible scientists agree to this in principle, even when they claim that the scientific world is subjectively constructed.

Eddington has said that the task of physics is "to formulate a system of laws applicable to the entities mentioned in the description, which shall be in every respect accordant with the actual correlations of sensory experience."[22] This description of physics avoids claiming that the description of the external world is real; it merely states that the description echoes sense

data.

In making such a statement Eddington represents accurately the sentiments of his contemporaries; physics only wishes to *describe* reality, not to determine whether it exists as it appears to us (realism), or only as it appears in our minds (idealism). Eddington assumes the existence of the external world, but--with others such as James Jeans--qualifies our knowledge of it by stating that the only data of "which we have any *direct* knowledge are our own thoughts and sensations. . . ."[23] Sensation is primary, yet the inference from sensation to a real external world is, as Planck noted above, no more than a metaphysical belief.

In this milieu physics assumes that the external world is real, but that it and its laws remain hidden and need the application of the resources of our *minds* if "the profound realities which conceal themselves behind natural appearances"[24] are to be revealed. Physics is the process of building an understanding of our perceptions of the universe into a coherent system; it is a mental process.

Einstein makes the involvement of the mind in science quite clear when he defines science as the

> century-old endeavor to bring together by means of systematic thought the perceptible phenomena of this world into as thorough-going an association as possible. To put it boldly, it is the attempt at the *posterior reconstruction of existence by the process of conceptualization.*[25]

Clearly Eddington's contemporaries acknowledged the existence of an external world, but recognized that our *knowledge* of it is generated through its interaction with our minds. This knowledge is thus subjective. It was self-evident in this milieu that anything we know is in our minds. The question remained, however, as to whether the laws of nature revealed to us through our *subjective* experience in science would constitute an *objective* reality; in other words, is the *physical* world (the world described by physics) real? From the opinions given by Eddington's contemporaries as cited above, the answer must be yes; but this objectivity is qualified, in that it is understood in Kantian fashion such that while the reality of the constructed world is assumed, the external, unconstructed world remains totally unknowable as it is in itself.

Another way of approaching this problem is that taken by Erwin Schrödinger, who had this to say on subject-object relations:

> The same elements compose my mind and the world. This situation is the same for every mind and its world. . . . The world is given to me only once, not one existing and one perceived. Subject and object are only one. The barrier between them cannot be said to have broken down as a result of recent experience in the physical sciences, for this barrier does not exist.[26]

From this brief remark it can be seen that Schrödinger made no distinction between the object as *known* and as it is in itself. This collapse of subject-object

distinctions places the existence of the *thing we know* firmly within the realm of consciousness; thus the thing that we know is the one that exists in our minds.

This constructed world that science knows is largely composed of the mathematical formulae that it uses to describe nature. This severely limits science in what it can say about reality, for as Jeans points out, "a mathematical formula can never tell us what a thing is, but only how it behaves; it can only specify an object through its properties."[27]

It must not be forgotten that mathematical formulae are, of course, human constructs. It should be clear that the only thing that science knows, namely mathematics, it knows because it has invented it. Sir James Jeans feels compelled to conclude from this that:

> The old dualism of mind and matter. . . seems likely to disappear, not through matter becoming in any way more shadowy and insubstantial than heretofore, or through mind becoming resolved into a function of the working of matter, but through substantial matter resolving itself into a creation and manifestation of mind.[28]

In short, the world according to physics, the one which it studies, is a mathematical, human construct.

A particularly interesting aspect of the mathematical nature of the physical world is the existence of so called *universal constants.*

The universal constants are of fundamental importance to physics because their existence reveals

that there is an objective reality informing the subjective, created world of appearances from which they are extracted. As Einstein would have it, there are "genuine universal constants" which are basic numbers that "are logically grounded and independent of any empirical determination or determinability";[29] these numbers are *a priori*.

This is very important. If these numbers do indeed reflect an *objective* world, then there are limits to the freedom we have in creating our physical world, and science indeed knows something of reality. Certainly Einstein believed that these constants are

> given in the structure of nature and [are] to be ascertained by observation and calculation. Scientific truth would thus depend on the structure of the universe of *real objects*. The theoretical scientist is therefore not 'free' to create theories; the dimensionless numbers would represent the restrictions of his freedom.[30]

Eddington and his contemporaries believed that the universal constants reveal the existence of an objective reality. This reality's characteristics are partially evident in the world of appearances, and from these appearances the values of the universal constants are derived. They are thus not completely subjective, but grounded in the objective reality which *causes* the appearances.

This is a valuable insight into their views, because Eddington's exposure of the illusory objectivity of

physics is often connected with his supposed belief in a constructed, idealist universe. It should be quite clear that Eddington's philosophy is not so facile. He has shown that there is a sense in which the physical world is indeed subjective, but in this he is no different than many of his contemporaries, when this viewpoint is balanced against a firm belief in the existence of an objective reality such as the universal constants partially reveal.

What exactly was the contemporary understanding of this reality which the constants partially reveal? Reality was more than mere appearances;[31] but beyond that assertion nothing definitive may be added, for even within the thinking of one scientist the definition of reality may vary wildly. This is especially true of Einstein, who sometimes said that which is "kickable" is real; at other times, theories which are confirmed by empirical evidence are granted reality; and sometimes pure thought constructs are said to be true. Clearly he had no well defined criteria for what "reality" is in science.[32] In contrast to Einstein, Eddington consistently held that in physics, "Observation is the High Court of Appeal", and while Einstein would be in general agreement, it is clear that at times Einstein thought that some things could be *true* without reference to observation.

For example, there is the story of Eddington's confirmation of the General Theory of Relativity via the eclipse experiment, one of three critical tests of the then highly disputed theory. When Ilse Rosenthal-Schneider saw the telegram from Eddington she questioned Einstein about it, expecting him to be exited at this proof of his theory. He is reputed to have been quite non-chalant, saying that if the experiment had in fact not confirmed the theory then "Da könnt' mir halt der liebe Gott leid tun. Die Theorie stimmt doch."[32]

Thus, far from restricting 'reality' to the observable world, Einstein claimed 'truth' for some *concepts* without reference to observation; they are true a *priori*. He wrote, "in thinking, we use, with a certain 'right', concepts to which there is no access from the materials of sensory experience if the situation is viewed from the logical point of view. . . ."[33] Any given reality is constructed out of concepts based on a *priori* principles; *physical* reality is based on metrical concepts.

The tendency of many scientists of this time period to recognize the influence of the mind in the construction of physical reality is based on the fact that they "had the greatest admiration for Kant's work, agreeing with his view that philosophy should be the basis of all sciences. . . ."[34] Philosophy occupied such

a key position because it was realized that Kant had elevated

> Newton's notions of absolute space and time to knowledge of the sort that we possessed before all else (i.e., a priori intuitions). . . these intuitions serve as basic organizing principles that enable our minds to construct knowledge from the potpourri of sense-perceptions. . . .[35]

Planck and Einstein, for example, were directly influenced by Kant; they are reported to have read Kant again and again.[36] Philosophy held great interest for them, since they saw that it affected their thinking as physicists. Indeed Einstein, parodying a famous saying of Kant's, said that "Epistemology without contact with Science becomes an empty scheme, Science without Epistemology is--in so far as it is thinkable at all--primitive and muddled."[37] For Einstein it is not sufficient to merely study the *facts* and create laws which describe the phenomena; rather, the goal of the construction of laws in science is a coherent world-view, which is a decidedly philosophical aim.[38]

Einstein readily admitted his dependence on Kant, and distinguished his own theoretical attitude from Kant's "only by the fact that we do not conceive of the 'categories' as unalterable (conditioned by the nature of understanding) but as (in the logical sense) free conventions."[39] As free conventions they were less a permanent feature due to the nature of human sensual and intellectual equipment, as they were temporarily accepted

tools for classifying and organizing perceptions.

This is an important change. What has happened in Einstein's thinking is that even Kant's categories are no longer absolutes; they are merely temporary conventions shared by the community of scientific minds.[40] This frees the mind to create many different physical worlds, each based on a different set of temporarily accepted conventions or assumptions. The recognition that any world view that science constructs is necessarily based on *a priori* concepts, is thus firmly entrenched in the scientific thinking of this milieu, and prompted Einstein to comment "Jeder hat seinen eigenen Kant,"[41] implying that every thinking scientist of the age had his own philosophical viewpoint, which was nonetheless based on Kant.

In Eddington's time there was general recognition of the constructed nature of the physical world. It was acknowledged that the assumption of certain parameters resulted in a certain picture of reality. The assumptions of physics precluded the inclusion of subjective, non-metrical experiences in its picture of reality; this is a self-imposed limitation of physics.

Eddington graphically illustrated the limits of science in his famous example of the elephant and the grassy hillside, where the amazing spectacle of an elephant careening down a hillside is reduced to a number

of pointer readings; the accurate description which physics gives seems to miss the drama and *reality* of the event. He provides other entertaining examples of the limits of science, including an adaptation of the old rhyme "The House that Jack built" which shows that the constructed world is totally circular, always defining its terms in terms of other terms defined by terms so defined.

By using anecdotes and clever illustrations, Eddington makes it quite clear that in every situation where we try to get at phenomena in the external world, there

> is always the triple correspondence--
> a) a mental image, which is in our minds and not in the external world;
> b) some kind of counterpart in the external world, which is of an inscrutable nature;
> c) a set of pointer readings, which exact science can study and connect with other pointer readings.[42]

What this means is that the things with which the physics of his milieu deals are not the things in themselves, but with the pointer readings which correspond in some way to those things.[43] Physics deals only in symbols, and only in those symbols which are congenial to mathematical manipulation by exact rules.[44] These rules have, of course been created by humans. Such notions are derivations of Kant's distinction between appearances and reality, where

> things as objects of our senses existing outside us are given, but we know nothing of what they may be in themselves, knowing only their appearances, that is, the representations which they cause in us by affecting our senses. Consequently I [Kant] grant by all means that there are bodies without us, that is, things which, though quite unknown to us as to what they are in themselves, we yet know by the representations which their influence on our sensibility procures us.[45]

The idea that an external reality exists, that it appears to us in some form via perception and measurement, but remains unknown to us as it really is, is here seen to be a Kantian idea; and as we have seen, it is an idea that has been absorbed by Eddington's contemporaries.

Some physicists would also go along with Kant's notion that "the understanding is the origin of the universal order of nature, in that it comprehends all appearances under its own laws and thereby produces, in an *a priori* manner, experience. . . ;"[46] and that "*the understanding does not derive its laws* (a priori) *from, but prescribes them to, nature.*"[47]

Eddington is then only reminding his fellow scientists of the importance of philosophy and epistemology for science when he notes that physical knowledge "has the form of a description of the world;"[48] a description whose elements will of course depend on the assumptions made prior to our perception of it.[49]

It was the realization of the involvement of our subjective minds in the construction of the physical world that led science to reevaluate its limits. It also

made it clear that physics' claims of absolute truth and universal knowledge were much too arrogant.

Heisenberg noted the change in science's self-evaluation, stating that

> Modern science, in its beginnings, was characterized by a conscious modesty; it made statements about strictly limited relations that are *only valid within the framework of these limitations. . . .* [but] *this modesty was largely lost during the nineteenth century. . . .* Today physics is undergoing a basic change, the most characteristic trait of which is a return to its original self-limitation.[50]

Other sensitive scientists became aware of the limitations of their art. In some cases it was a painful discovery, as comes through the following statement by Schrödinger:

> The scientific picture of the world around me is very deficient. It gives a lot of factual information, puts all our experience in a magnificently consistent order, but it is ghastly silent about all and sundry that is really near to our heart, that really matters to us.[51]

This theme is of course carried to great lengths by Eddington, who made it quite clear that science cannot explain even thought or consciousness, the existence of which is "one of the indisputable facts of the world."[52] Neither can physics explain one of its basic building blocks, the atom, because the "physical atom is, like everything else in physics, a schedule of pointer readings."[53] Sir James Jeans concludes that the "universe cannot admit of material representation, and the reason, I think, is that it has become a mere mental

concept.[54]

If the universe is a "mere mental concept" or "mind stuff" in Eddington's terms, then the physical world is no more than a metaphor created in the human mind. Indeed, Kant indicated that the objects of nature "must be construed to be nothing but mere representations in us, and exist nowhere but in our thoughts."[55]

This concept is perhaps most forcefully expressed by Schrödinger--a respected scientist who was also acquainted with Vedantic Hinduism--when he says "I think, that I--I in the widest meaning of the word, that is to say, every conscious mind that has ever said or felt 'I'--am the person, if any, who controls the 'motion of the atoms' according to the Laws of Nature. . . . Hence I am God Almighty. . . ."[56] Along the same lines, he also claims that the "reason why our sentient, percipient, and thinking ego is met nowhere within our scientific world picture can easily be indicated in seven words: because it is itself that world picture."[57]

While statements such as these do represent a radical departure from uncritical realism, it must be remembered that the scientists making them do not deny that the existence of a real world which forms the ground and goal of their science is a given without which they could not function. It is in relation to this that these radical statements should be taken.

Sir James Jeans reiterates this important point, namely that these scientists are not proposing idealism, but a restructuring of scientific epistemology along lines that would define the limits of science, and what it is that physics can know. In his words, the recognition of the constructed nature of reality

> may suggest that we are proposing to discard realism entirely and enthrone a thoroughgoing idealism in its place. Yet this, I think, would be too crude a statement of the situation. If it is true that the 'real essence of substances' is beyond our knowledge, then the line of demarcation between realism and idealism becomes very blurred indeed; it becomes little more than a relic of a past age in which reality was believed to be identical with mechanism.[58]

In short, scientists in Eddington's time were suggesting that it is necessary to move beyond the mechanical world-view, if we are to understand how the seemingly totally subjective universe they describe as being the world of physics today, can at the same time be grounded in the objective reality which science seeks to discover.

In place of the mechanical world-view of uncritical realism, Eddington and his contemporaries suggested that the external world is of a constructed nature; they thought that physical reality was no more than a concept. Schrödinger, for example, postulates that the way in "which the world-concept produces itself" is that "several domains of 'private' consciousnesses partly overlap. The region common to all where they all overlap is the construct of the 'real world around us.'"[59]

Similarly, Eddington suggests that much

> that is in any one consciousness is individual, much is apparently alterable by volition; but there is a stable element which is common to other consciousnesses. That common element we desire to study, to describe as fully and as accurately as possible, and to discover the laws by which it combines now with one view-point, now with another. This common element cannot be placed in one man's consciousness rather than in another's; it must be in neutral ground--an external world.[60]

Eddington, like Schrödinger, recognizes that reality is that which is in our conscious minds; its objectivity rests in collective subjectivity. The commonality of the contents of our consciousnesses *suggest* the existence of some external reality, but whether or not this "neutral ground" represents the ultimate reality that science formerly thought it had a hold of is uncertain. Sir James Jeans is quite sure that we still have no hold on ultimate reality; he claims that the

> essential fact is simply that *all* the pictures which science now draws of nature, and which alone seem capable of according with observational fact, are *mathematical* pictures. Most scientists would agree that they are nothing more than pictures--fictions, if by fiction you mean that science is not yet in contact with ultimate reality. . . . Many would hold that. . . the outstanding achievement of twentieth-century physics. . . is the general recognition that we are not yet in contact with ultimate reality. To speak in terms of Plato's well-known simile, we are still imprisoned in our cave, with our backs to the light, and can only watch the shadows on the wall.[61]

Plato's simile of humanity's quest for truth beautifully illustrates the difference between scientific and mystical apperception. In mystical awareness,

> Reality is apprehended directly and immediately, meaning without any mediation, any symbolic elaboration, any conceptualization, or any abstractions; subject and object become one in a timeless and spaceless act that is beyond any and all forms of mediation.[62]

In contrast,

> when the physicist 'looks at' quantum reality or at relativistic reality, he is *not* looking at the 'things in themselves.' at noumenon, at direct and unmediated reality. Rather, the physicist is looking at *nothing but a set of highly abstract differential equations*--not at 'reality' itself, but the mathematical symbols of reality. . . .[63]

It is this realization, that science does not deal with reality, but only with our conceptions of it, that makes much of Eddington's thought so captivating. In his private life as a Quaker he regularly felt the closeness of God, and was sure that this represented unmediated experience of reality; as a scientist, he was fully aware that his arts could never lead him to that same reality. It was science's false claim to be exploring the real world that he sought to expose to critical examination; and thereby to indirectly reinforce the validity of Quaker religious experience.

CHAPTER TWO

Eddington on Reality

> the truth we seek in science is. . . not bound up with any opinion as to the status of that world--whether or not it wears the halo of reality, whether or not it is deserving of 'loud cheers.'[1]
>
> Eddington

> physical reality is the synthesis of all possible aspects of nature.[2]
>
> Eddington

In this chapter, I want to focus on Eddington's conception of reality. This will involve an examination of his views regarding the status of what we normally call reality, of what the basis for this external world is, and of what really *is*. The underlying reality is the ultimate reality, but is inaccessible to science; it is however, accessible by spiritual means, or in secular terms, to the mind. The conclusion is thus that what we normally call reality is of a mental character, and all that we perceive to be the everyday world is constructed out of "mind stuff".

Our conception of reality has changed since the advent of relativity theory. Eddington was one of the

first scientists to fully understand this; he was also one of the first to understand the mathematical aspects of relativity theory, and the first to expound on its implications for our understanding of reality. Relativity theory exposed the subjective nature of our knowledge of physical reality. This means, as Eddington says, that 'space is conventional'. The implication is that "other conventional meanings of space and time are possible;"[3] space and time are not objective realities but constructs.

Eddington realized that the change that relativity theory forced onto physics dealt with the way in which scientists viewed their work; they no longer thought themselves to be studying reality, but only the structure of conventional reality as given in physical laws. This change that relativity theory brought to the practice of scientific research into the nature of the external world had to do not so much with the material that physics investigates, but with a changed attitude towards that material. The subject of physics is no longer assumed to be objective substance, for the substantiality of things is now seen to be a trick of the mind.

Eddington appreciated the role of mind in our understanding of the physical world as early as 1923, when he said:

> In one sense deductive theory is the enemy of experimental physics. The latter is always striving

> to settle by crucial tests the nature of the fundamental things: the former strives to minimize the success obtained by showing how wide a nature of things is compatible with all experimental results.[4]

What this means is that our *image* of reality is created in our minds, and is not merely a reflection of an objectively existing external reality. To explain, the results of an experiment do not tell us a great deal about reality at all; rather, they only show that reality *can* conform to the expected results of the experiment. This means that a body of knowledge constructed out of experimental results is not objective at all, but subjective; the knowledge is based on the kinds of questions asked, and reveals more about those questions than about the reality which answers those questions. The structure of the physical world depends entirely on the epistemological presuppositions of the physicist conducting the experiments, because the "physical universe is the world which physical knowledge is formulated to describe; there is no difference between the physical universe and the universe of physics."[5]

To this subjective nature of reality--constructed from the presuppositions of the scientists--was now added the further subjectivity of all possible viewpoints, as revealed by the introduction of relativity theory. Eddington acknowledged the subjective nature of all of our knowledge of the external world. He called physical reality the structure of the external world, and not the

external world itself; "Since the external world is introduced as a receptacle of structure, our knowledge is limited to structural knowledge; and physical science is the study of this structural knowledge."[6]

This analysis of the situation in which physics finds itself leads inexorably to the conclusion that the universe as we know it is not objective--or at least to the conclusion that it is difficult to know when, if ever, the object being described by physics has an objective existence. Indeed, in Eddington's mind, "the physical analyst is an artist in disguise,"[7] and there is no such thing as metaphysically "real existence"[8] of which we can have knowledge apart from its existence in human consciousness.

The reality with which physicists work is the external world as constructed from the contents of many different consciousnesses; that is, "the externality of the physical world results from the fact that it is made up of structures found in different consciousnesses;"[9] it is only in the common contents of consciousness that the external world can be said to exist, and the subject of physical research is that part of our collective subjective experience which we all have in common. The role of mind is thus all important to an understanding of the physical world.

The Role of Mind

Eddington has demonstrated that the external world constructed by physics is like "the house that Jack built" and, that physics maintains its independence from all "extraneous support like a serpent swallowing its own tail."[10] The problem arises, if mind is wholly responsible for the world as we know it, why should we assume that the world we have constructed bears any relation to the "real" world at all? What gives the external world of physics any "actuality?" Unfortunately,

> Actuality--that which distinguishes this world from many other possible worlds consistent with the laws of nature--is not susceptible of definition without trespassing beyond the frontiers of physics.[11]

The only definition possible is trivial, namely that "*actuality* denotes something which is significant and detectable by experience."[12] Eddington does not find this definition to be terribly helpful.

Pursuing the idea further, Eddington finds it useful to isolate theoretical physics from experimental physics. When this is done, it can be seen that the latter is of course very much concerned with the "actual" world, whereas the former considers it only to be a special case out of all possible worlds. In theoretical physics then, actuality is superfluous. Since theoretical physics is unable to provide criteria for actuality to experimental physics, the latter must fend for itself, and Eddington

claims that the only recourse it may have is to consciousness:

> If then we consider a world entirely devoid of consciousness (as we not infrequently try to do), there is, so far as we know, no meaning whatever in discriminating between worlds A and B. The mind is the referee who decides in favour of A against B. We cannot describe the difference without referring to a mind. The actuality of the world is a spiritual value. The physical world at some point (or indeed throughout) impinges on the spiritual world and derives its actuality solely from this contact.[13]

Spirit here, and throughout Eddington's works, is synonymous with mind.[14] Thus, in the above reference, Eddington is saying that the underlying reality contacts or 'impinges upon' our minds, and it is from this contact that the physical world derives its actuality. Apart from mind, we have no concept of the world.[15]

Physics, however, makes all kinds of claims about the structure of reality; what is the nature of this reality?

Recall Eddington's story about the closed world of physics, in which physics is compared to the "House that Jack built", where the external world is made up of only potentials, force, mass and so forth, and these components of the "House that Jack built" are themselves constructs, defined in terms of each other in an endless circle.[16] The only way to break out of the circle and give some meaning to the components of the external world is if some connection to consciousness is made--to the person who knows what matter is. Eddington's conclusion

from this understanding of physics is that "it appears also that the value to be attached to physical entities, such as mass and force, is. . . ultimately a value for consciousness."[17] There is no escape from the self-enclosed world of physics to a world of meaning except through consciousness.

Consciousness selects certain characteristics of the underlying reality and declares them to be features of physical reality.[18] What is to prevent us from all having wildly different realities? Why should my subjective experiences bear any relation to yours? Eddington speculates that the reason our subjective experiences are all so similar is because of the existence of an underlying reality which informs our experiences, and because of natural selection.

This is of course, also the supposition of Kant, who thought that while we do not know the thing in itself but only its appearances, it is necessary for there to be a thing in itself, otherwise "there would be no reason for the judgments of other men necessarily agreeing with mine [Kant] if it were not the unity of the object to which they all refer and with which they accord. . . ."[19] There would seem to be some necessity for the existence of an external reality.

To illustrate how the mind constructs reality, take one of the fundamental characteristics of our common

reality, its permanence. Eddington supposes that

> the mind has by diligent search picked out the possible constructs which have this permanence in virtue of their mode of construction, and by giving these value and ignoring the rest has imposed a law of conservation of the things of value.[20]

That the mind should do this only makes sense, since as Eddington notes, it would be a function of natural selection to weed out minds which did not pick up on permanent objects--they "would have short shrift in the struggle for existence."[21]

Thus, even though we know that substance is composed largely of empty space, the make-up of our minds is such that we hold it to be a solid. Eddington goes so far as to claim that "the mind's search for permanence has created the world of physics. . . ."[22] "Objects" in the physical world are not *necessarily* permanent.

The construction of the external world is not as radical an idea as may be thought, especially when it is seen how pervasive it is in all our knowledge processes. There is literally nothing we can know without constructing it. To illustrate this, it may be useful to quote at length a remarkable example of Eddington's.

At an "Evening Discourse to the British Association at Oxford, 1926" he paused meditatively, viewing a photograph of a Wilson cloud chamber track, on which the photographer had inadvertently placed a large thumbprint. At length he resumed speaking,

> I wonder if there is an undercurrent of suspicion in your minds, that there must be something fake about this photograph. Are these really single atoms that are showing themselves--those infinitesimal units which not many years ago seemed to be theoretical concepts far outside any practical apprehension? I will answer that question by asking you one. You see a dirty mark on the picture. Is that somebody's thumb? If you say Yes, then I assure you unhesitatingly that these streaks are single atoms. But if you are hypercritical and say "No, that is not anybody's thumb, but it is a mark that shows that somebody's thumb has been there", then I must be equally cautious and say that the streak is a mark that shows where an atom has been. The photograph, instead of being the impression of an atom is the impression of the impression of an atom, just as it is not the impression of a thumb, but the impression of the impression of a thumb. I don't see that it really matters that the impression is second-hand instead of first-hand. I do not think that we have been guilty of any more faking than the criminologist who scatters powder over a finger-print to make it visible, or a biologist who stains his preparations with the same object.[225]

We see from this that Eddington held all physical knowledge to be derived, or constructed, from impressions, whether it be knowledge of thumbs from thumbprints or through direct observation of the something at the end of my arm which I know as my thumb; all knowledge is theory-laden, constructed in our brains on the basis of previous theories.

To science it does not matter how the information is obtained, so long as it yields useful results. Even if it is the mind which selects data, or the scientist who selects experiments, this subjectively constructed external world conforms to certain expectations and these can be predicted. But what is being predicted is the

behaviour of things, and their relationships to each other; science is not describing the actual things themselves.

At the risk of oversimplifying, all that Eddington is saying is that mind cannot perceive the actual things "out there" in the external world, but only their relationships and interactions, and thus must *construct* the objects whose relationships it is studying. It is the primary achievement of physics in this century to have realized that it studies a "world of shadows", a world of structures and relationships, and not things in themselves.[24]

As one of the few people in his milieu that really understood relativity theory, Eddington had great appreciation for its power and usefulness to the world of science. Yet he also saw that it did not reveal reality as it is--that science is unable to grasp the reality behind the constructs and symbols it works with. Thus in spite of the power of relativity theory, it has severe limitations; in "regard to the nature of things, this knowledge is only an empty shell--a form of symbols. It is knowledge of structural form, and not a knowledge of content."[25]

The limitations which relativity places upon the observer led him to conclude that we are "unable to reach by physical methods a purely objective world, and it

would seem to follow that all the entities of physics have the partial subjectivity of the world to which they belong."[26] To put it another way, the physical world is a subjective creation of the mind, and without mind, it simply does not exist: "if we remove all subjectivity we remove all the fundamental laws of nature and all the constants of nature."[27] Recognizing that the subjectivity of the physical world is thoroughgoing,[28] Eddington admits that it is really impossible to know if we have learned anything of the external world, of reality, at all. He put his doubts into poetic form in this famous passage:

> We have found a strange foot-print on the shores of the unknown. We have devised profound theories, one after another, to account for its origin. At last, we have succeeded in reconstructing the creature that made the foot- print. And Lo! it is our own.[29]

The Underlying Reality

Eddington has shown us that science deals with symbols and structures, with mental constructs derived from our collective impressions of the underlying reality. But what is this underlying reality?

To introduce what Eddington thought to be the underlying reality, it is instructive to quote his famous[30] discussion of the "Two tables":

> I have settled down to my task of writing these lectures and have drawn up my chairs to my two tables. Two tables! Yes; there are duplicates of every object about me--two tables, two chairs, two pens. . . . whenever I begin to scratch the first

> thing I strike is--my two tables.
> One of them has been familiar to me from earliest years. . . . . It has extension; it is comparatively permanent; it is coloured; above all it is *substantial*. By substantial I do not merely mean that it does not collapse when I lean upon it; I mean that it is constituted of "substance" and by that word I am trying to convey to you some conception of its intrinsic nature. It is a *thing*. . . . it is the distinctive characteristic of a thing to have this substantiality, and I do not think substantiality can be described better than by saying that it is the kind of nature exemplified by an ordinary table.
> Table No. 2 is my scientific table. . . . It does not belong to the world previously mentioned. . . .[and] is mostly emptiness. . . .Notwithstanding its strange construction it turns out to be an entirely efficient table. . . .
> There is nothing *substantial* about my second table. . . . [yet] modern physics has by delicate test and remorseless logic assured me that my second scientific table is the only one which is really there--wherever "there" may be.[31]

Two tables, and neither are truly real. The first table has been shown to be a fiction both by modern physics, and by Eddington's analysis of the involvement of mind in its creation. The second table, which modern physics claims is "really there" Eddington has also shown to be subject to creation by mind in a self-contained loop of definitions. What then is "really there"?

That there is some kind of underlying reality that *informs* our collective subjective impressions Eddington does not doubt any more than any other scientist.[32] Its existence is a given; however, it is very unclear what its nature is.

When Eddington uses terms like objective, absolute and universal in reference to the underlying reality, it

is tempting to assume that he meant that it had a physical, tangible, nature.[33] Surely these terms suggest an objectively existing "something" which has these characteristics? In my opinion it is deceptive to interpret Eddington in this way. While he may have held to a belief in an underlying reality, that reality was not accessible to physical inquiry.

To explain, Eddington's use of these terms is, in most instances, in reference to items of relative objectivity. For Eddington, there is a large difference between an "object" which is assumed to exist as it appears to us, and our "objectification" of something which presents itself to our collective minds as "subject". He warns that

> By recognizing other consciousnesses coequal with our own we had already committed ourselves to the acceptance of a realm outside the individual consciousness. Nevertheless it is a new step of great magnitude when, by the discovery of similar structures common to all normal consciousnesses, we introduce an external world containing the original structure of which they are reproductions.[34]

Thus the "objective" world is not some independently existing thing but rather is "the symposium of the worlds presented to different viewpoints."[35]

Further, by "absolute" he means the nature of a thing when taken from all possible viewpoints, while "universality" is used to refer to an area of common agreement. These terms then, always refer to the objects

of human consciousness, and are not to be taken as referring to things existing apart from human consciousness.

Nevertheless, some "things" Eddington acknowledges as having some kind of existence apart from human consciousness: the earth existed before humanity did, and even then exerted gravitational force on passing light beams; the speed of light; Planck's constant *h*; geodesics described by a freely falling body. All of these are things Eddington considered granting status as absolutes, or universal constants.[36] But the objective nature of even these things must be tempered by the knowledge that Eddington considered even space and time, in which these phenomena exist, to be conventional.[37]

It is only in so far as "something" is the source of our sensations that Eddington can be conceded to have had an idea of an external reality; an underlying reality which stimulates consciousness into recognizing its existence. As to the nature of this existence we can know nothing. The world which we know exists only in our minds. As Eddington clearly states:

> Accordingly my subject of study becomes differentiated into the contents of many consciousnesses, each content constituting a *view-point*. There then arises the problem of combining the view-points, and it is through this that the external world of physics arises. Much that is any one consciousness is individual, much is apparently alterable by volition; but there is a stable element which is common to all consciousnesses. That common element we desire to study, to describe as fully and

> accurately as possible, and to discover the laws by which it combines now with one view-point, now with another. This common element cannot be placed in one man's consciousness rather than in another's; it must be in neutral ground--an external world.[38]

Of this neutral ground, nothing is known other than its structure; but it does exist.

The underlying reality is a given, and Eddington assumes that it is this non-constructed foundational reality which informs our observations, and leads to the construction of the physical world. There must be "something" out there for the mind to select sense impressions from, since, "[s]election implies something to select from. it seems permissible to conclude that the material on which the selection is performed is objective."[39]

The underlying reality is objective. But objective here has two main meanings: first, a thing studied by science, a thing which Eddington has shown to be subjective; second, a really existing thing--part of the underlying reality of which we know nothing. The underlying reality is objective, but unknown.

There is some relationship between the external world and the constructed, "objective," physical world, but there can be no way of knowing if there is a one to one correspondence between the substratum of reality and our constructed external world; nevertheless, "it is clear that there is a certain ordering of things and events

outside us. . . ."[40] which is reflected in the orderliness of our subjective constructions. Thus, while the constructed world may reveal nothing of the nature of the "things" in the underlying reality, it shares a similar structure. That this should be so is explained by Eddington as follows:

> There is one type of observation which, we can scarcely doubt, must be independent of any possible circumstances of the observer, namely a complete coincidence of space and time. The track of a particle through four-dimensional space-time is called its world-line. Now, the world-lines of two particles either intersect or they do not intersect; the standpoint of the observer is not involved. In so far as our knowledge of nature is a knowledge of intersections of world-lines, it is absolute knowledge independent of the observer.[41]

In other words, events that happen in the underlying reality are manifest in our constructed reality as well. More generally, in forming a structuralist view of the external world, Eddington is saying that the relations between the relata can be known, even though the relata cannot be known. But, as Eddington is quick to note, this still does not mean that we know anything of the underlying reality. We are still only aware of the external world through the synthesis of our collective subjective experience, and perspectives other than human could conceivably construct a very external world; there is no reason for assuming that our perspective of the underlying reality is any more correct than any other formulation thereof. Indeed, "reality is only obtained

when all conceivable points of view have been combined."[42] Because the external world is based not on some substantial reality--some ultimate reality--but on the "symposium of the worlds presented to different view-points,"[43] the total number of observers represents the limit of our understanding of reality, and given a finite number of observers, we will necessarily never have a full understanding of the external world. Reality as such must always remain beyond the scope of physics.

It is clear that Eddington wished to know something of the underlying reality which formed the foundation for our observations; but, ultimately he realized that such knowledge is unavailable to us. He concludes that "*Something unknown is doing we don't know what*--that is what our theory amounts to."[44]

Science may be able to understand the relations between various events in the fabric of space and time, and be able to describe those accurately, but it must be admitted that an understanding of relations does not amount up to an understanding of the things related by them.[45] To illustrate his point he quotes 'Jabberwocky':

> The slithy toves
> Did gyre and gimble in the wabe.[46]

The point is that some kind of action is indicated between some kind of things, but an actual knowledge of the content of the things and the actions eludes us in this poem, just as it does in attempting to come to an

understanding of the external world.

Through science we can come to an understanding of the external world that we have subjectively constructed out of our common perceptions; however, we cannot envision the reality behind it all. When all is said and done we have to admit defeat and confess that we "can grasp the tune but not the player."[47] Some other means must be employed to get at ultimate reality.

In short, the world of physics is not objective; yet there is an external reality--which may be objective or not--which physics is unable to grasp. Eddington suggests that other methods may, however, be able to get at external reality. One such approach is psychology, specifically through the experience of time.

While Eddington acknowledges that he is not competent to discuss psychological matters, he plunges on ahead anyway in order to explore what to him seems to be a highly suggestive link between the experience of time and the going on of time in the universe.

For Eddington, the perception of time represents a link between the scientific concept of entropy and the awareness of becoming. He proposes "Entropy-gradient is then the direct equivalent of the time of consciousness. . . ."[48] because

> Just as certain physical disturbances entering the brain cells *via* the optic nerves occasion the sensation of light, so a change of entropy, either in the brain cells generally or in special cells,

> occasions the sensation of time succession, the moment of greater entropy being *felt* to be the later.[49]

Eddington speculates that in this feeling of becoming we experience a "true mental insight into the physical condition that determines it."[50] He realized, of course, that he was claiming that the mind has access to reality in a way impossible to physics, that suggesting that the feeling of becoming is linked to entropy "is tantamount to an admission that consciousness, looking out through a private door, can learn by direct insight an underlying character of the world which physical measurements do not betray."[51] In other words, Eddington is saying that consciousness is directly aware of reality, and *knows* reality in a way that is totally beyond physical methods. He states boldly that our experience of time is clearly an example of a superior way of knowing:

> It is so welded into our consciousness that a moving on of time is a condition of consciousness. We have direct insight into 'becoming' which sweeps aside all symbolic knowledge as on an inferior plane. If I grasp the notion of existence because I myself exist, I grasp the notion of becoming because I myself become.[52]

Knowledge of time is direct knowledge; through it we know the dynamic nature of the external world, a nature which is intrinsic to it.[53] For Eddington, in "any attempt to bridge the domains of experience belonging to the spiritual and physical sides of our nature, Time occupies the key position."[54] The reason for the importance of

our experience of time is its direct, unmediated apprehension by consciousness. It is worth quoting Eddington at length on this subject as much of his epistemology is clarified in the following short paragraph:

> we must regard the feeling of "becoming" as (in some respects at least) a true mental insight into the physical condition which determines it. It is true enough that whether we are dealing with the experience of "becoming" or with the more typical sense-experiences of light, sound, smell, etc., there must always be some point at which we lose sight of the physical entities ere they arise in new dress above our mental horizon. But if there is any experience in which this mystery of mental recognition can be interpreted as *insight* rather than *image building*, it should be the experience of "becoming"; because in this case the elaborate nerve mechanism does not intervene. That which consciousness is reading off when it feels the passing moments lies just outside its door. Whereas, even if we had reason to regard our vivid impression of colour as insight, it could not be insight into the electric waves, for these terminate at the retina far from the seat of consciousness.[55]

Through the experience of time, we have a true insight into the dynamic nature of the external, underlying reality.[56]

Nevertheless, methods of getting at the underlying reality are beyond the bounds of science. Those experiences which impinge directly on our consciousnesses and with which we grapple without the aid of metrical aids are not within the domain of physics. When dealing with the world which physics investigates, Eddington holds strictly to a constructivist reality in which "the stuff of the world is mind-stuff,"[57] not objective

reality.

It is so obvious to Eddington that physics deals only with *concepts* that he sometimes expresses puzzlement at the insistence of most physicists, who are dealing with correlations of experience, on claiming that they are describing "the content of an absolute objective world." He feels that more progress could be made if it would be admitted that physics deals with relations between relations, and if no claims were made as to the absolute nature of the things related; for any attempt at understanding what they are would be necessarily subjective. That there is an underlying structure to those correlations of experience which physics describes as relations between relata is not denied; what is denied is that we can know via the scientific method--or any other--what it is.[58]

Eddington's conclusion is that the world is made of "mind-stuff", and that it must be admitted that

> We have only one approach [to an understanding of reality's nature], namely, through our direct knowledge of mind. The supposed approach through the physical world leads only into the cycle of physics, where we run round and round like a kitten chasing its tail and never reach the world-stuff at all.[59]

Eddington admits that the idea that "the substratum of everything is of mental character,"[60] is difficult for anyone to accept, but "no one can deny that mind is the first and most direct thing in our experience, and all

else is remote inference--either intuitive or deliberate."[61] In the final analysis the only reality that we can thus really know is our own internal, spiritual reality.[62]

Spiritual Reality

When Eddington began to take his speculations regarding the nature of reality into the spiritual or mental realm, he knew he was treading on dangerous ground. He made no attempt to prove the existence of God from science, nor to show what the nature of spiritual reality was. Rather he sought merely to give religion and science room to work at discovering the nature of reality free from each other's interference, and to give credence to each approach.

Eddington summarizes his endeavor as intending only to give some idea of the

> general direction in which scientific thought appears to be tending (rightly or wrongly) now that it is confronted with a conception of the material world widely different from that which was the basis of disputes between science and religion in the last century.[63]

And of course the key point in this different "conception of the material world" is that it is made up of "mind stuff", that mind is the author of creation.

Eddington says essentially the same thing again when he says that

> Our philosophy has led to the view that in so far as we can separate the subjective and objective

> elements in our experience, the subjective is to be identified with the physical and the objective with the conscious and spiritual aspects of experience.[64]

This is a profound reversal of the usual way of understanding objectivity and subjectivity. For Eddington the physical world is composed of the contents of our collective consciousnesses, and is thus essentially subjective. In contrast, the experiences of our own consciousness are presented to our minds directly, and these experiences are thus objects for our minds. In other words, because "mind is the first and most direct thing in our experience, and all else is remote inference" the only objects presented to us for study are the contents of our own minds. These "subjective" contents of consciousness are thus the only real "objective" things in existence. This has of course, been the standard view of how one is to make "objective" statements about religious experience; but Eddington is expanding the territory and claiming that this is true not only for religion, but also for science--both fields ultimately only study the contents of consciousness. If this is true, then Eddington has helped to put religion on the same experimental footings as those of science. He puts it this way:

> All I would claim is that those who in the search for truth start from consciousness as a seat of self-knowledge with interests and responsibilities not confined to the material plane, are just as much facing the hard facts of experience as those who

> start from consciousness as a device for reading the indications of spectroscopes and micrometers.[65]

There is thus a distinct parallel between science and religion, and that is that both start with the contents of consciousness and from these construct a world that seems to fit the observations.

Taking the parallel further, Eddington points out that as physics has come to conclude that there is a neutral ground beyond its grasp that informs its observations, why could there not be something beyond our spiritual grasp as well? He asks,

> Shall I not also add that even as light and colour and sound come into our minds from a world beyond, so these other stirrings of consciousness come from something which, whether we describe it as beyond or deep within ourselves, is wider than our own individual personality?[66]

Eddington thus establishes the existence of a spiritual reality, a reality just as objective/subjective as the everyday external world. The basis for such a belief is the experience of it, just as in the physical world; it is not just a belief, pulled out of thin air:

> This image of the divine nature is not a convenient fiction for use in workaday life, to be discarded in favour of a system of equations when scientific accuracy is required. If the hypothesis is correct, it signifies a direct relation of spirit to spirit which can scarcely be made clearer by an irrelevant excursion into the cycle of physical definition where the differential equations take their rise; it is more nearly expressed by reference to a relationship of spirit to spirit on the human plane--a relation which means much more than physical science is able to formulate. As to this further question the scientist and the religious teacher may well be content to agree that the value of any

> hypothesis extends just so far as it is verified by actual experience.[47]

Religion is able to speak to questions of meaning in human relations that physics is not even able to formulate. Religion speaks to the question of why we even bother doing physics at all. In this it transcends physics.

Eddington analyzes two approaches to reality--science and religion--and arrives at two conclusions: First, that neither approach is able to get a grasp on reality; and second, that the religious approach has a chance to attain to some knowledge of reality.

Eddington says that both science and religion start from the contents of consciousness, and both science and religion are unable to say what it is that informs their observations. Eddington held the nature of ultimate reality to be ineffable. At the same time, the very nature of the spiritual approach to reality, which attempts to come to grips with mental constructs, places it one step closer to reality than physics, which often forgets that it is studying objectifications of consciousness, or objects constructed by mind from its mental constructs, placing physics at a step further removed from reality than religion.

It is this method of religion which places it closer to reality, sparking comments like those above regarding a relationship on the "human plane" the likes of which

physical science is unable to formulate. It is this which enables religion to speak to those things that the physical description of the world leaves out, those things which are near and dear to us. Eddington also feels that "experience--that is to say, the self *cum* environment--comprises more that can be embraced in the physical world. . . ."[68] By virtue of its method, religion is in a better position to speak about this "more" which physics cannot address. But the nature of this "more" cannot be clarified through religion, since it is ultimately beyond our grasp.

In short, Eddington's assessment of the inability of physics to get at the stuff of ultimate reality spreads also to religious methods.[69] Nevertheless, he is clearly saying that while there are aspects of reality "unattainable by the methods of physics," a search into the process--in the study of epistemology--by which the mind regains "from nature what the mind has put into nature," must surely prove to be fruitful in the struggle of getting at truth.[70]

This is again emphasized when Eddington contrasts the kinds of things that physics can say about God versus what religion says:

> For the sphere of the differential equations of physics is the metrical scheme extracted out of the broader reality. However much the ramifications of the cycles may be extended by further scientific discovery, they cannot from their very nature trench

> on the background in which they have their being--their actuality. It is in this background that our own mental consciousness lies; and here, if anywhere, we may find a Power greater than but akin to consciousness. It is not possible for the controlling laws of the spiritual substratum, which in so far as it is known to us in consciousness is non-metrical, to be analogous to the differential and other equations of physics which are meaningless unless they are fed with metrical quantities. So that the crudest anthropomorphic image of a spiritual deity can scarcely be so wide of [sic] the truth as one conceived in terms of metrical equations.[71]

God, or ultimate reality, is thus more closely approached through even crude anthropomorphisms than through physics; however, Eddington does not wish to prove God in this manner. He respects the mystery of the divine nature far too much to attempt that. Rather, he wishes merely to introduce the possibility of God, the possibility that there is more to reality than reductionist science has claimed.

> Just as matter must shed its conception of substantiality, so existence must shed its halo, before we can admit it into physical science. But clearly if we are to assert or to question the existence of anything not comprised in the external world of physics, we must look beyond the physical definition. The mere questioning of the reality of the physical world implies some higher censorship than the scientific method itself can apply.[72]

It is this appeal to something beyond physics that marks Eddington. He has seen the reductionist tendencies of his science descend to the dangerous level of reducing "God to a system of differential equations. . . ;"[73] when in fact, the "external world of physics has been formulated as an answer to a particular problem

encountered in human experience."[74] To claim that this is the only problem that matters is very dangerous. Eddington has alerted us to the danger of doing so, and pointed out that there is much more to reality than provided by physics in constructing a physical world.

Structured Reality

Eddington thought he had abolished the dualism of consciousness and matter by noting that all "physical knowledge is structural knowledge. . . ."[75] and that "the physical universe is a structure. . . ."[76] The nature of this structure is deducible from the nature of our human intellectual and sensory equipment. As Eddington says,

> the influence of the sensory equipment with which we observe, and the intellectual equipment with which we formulate the results of observation as knowledge, is so far-reaching that by itself it decides the number of particles into which the matter of the universe appears to be divided. . . .[77]

In other words, from knowledge of human nature we can deduce--*a priori*--the structure of the physical world.[78] Furthermore, because Eddington's epistemological method reveals not only known facts but can be used to predict currently unknown facts, knowledge derived in this fashion is not only a priori, but also synthetic.[79]

Further, this view is only possible because Eddington regards the *universe* to be at least partially subjective,[80] and its laws to be totally subjective.[81] Eddington accepts this subjectivity of the physical

world, and views the *universe*--or the structured whole which physics creates--as a "description of the world."[82] As such, the *universe* is for Eddington no more than a *form of thought*, or *general concept*, and "it may be said that Eddington's general concepts constitute a modern edition of the famous Kantian 'Verstandesformen' or categories."[83]

In spite of this similarity, there is an important difference between Eddington's and Kant's understanding of the reality of the physical world. In Kant's thought, nature as *Erscheinung* is wholly subjective, that is, appearances have nothing in common with the Ding-an-Sich. In contrast, Eddington's physical universe is only partially subjective, and contains some hints of an external reality. Eddington says: "In our view the physical universe is neither wholly subjective nor wholly objective--nor a simple mixture of subjective and objective attributes."[84] The objective part of the universe, however, is *spiritual*:

> The purely objective sources of the objective element in our observational knowledge have already been named; they are *life, consciousness, spirit.*[85]

Eddington does not develop this objective spiritual knowledge into a transcendental discipline as Kant did, perhaps because his Quaker induced appreciation of things mystical discouraged speaking of the ineffable. Eddington's conclusions regarding the credibility of both

scientific and religious approaches to an understanding of nature have profound implications for the relationship between science and religion. As he sees it physics is the science which studies the problem of humanity's relationship to the external world, it studies the structures and behaviours of the objects impinging on our consciousnesses. The

> realisation that physical knowledge is concerned only with structure points the way by which the conception of man as an element in a moral and spiritual order can be dovetailed into the conception of man as the plaything of the forces of the material world.[96]

Science deals with structures, giving answers to questions regarding our physical environment, whereas religion confronts questions of meaning, speaking to that part of our persons to whom it matters what the answers are.[97]

CHAPTER THREE

Eddington on Consciousness and the Limits of Science

> The only subject presented to me for study is the content of my consciousness.[1]
>
> Eddington

Eddington envisioned two kinds of reality. One of these realities is the one which science works with, and it is a mere shadow reality, a subjectively constructed universe. The other is the remainder, the stuff with which physics can by definition not deal with, but which forms the foundation for the constructed universe of physics.[2]

To put it differently, Eddington attempted to show that the world of physics is a constructed one, one which is built according to the presuppositions of the researchers, and is thus subjective. He repeatedly emphasized that "all knowledge of our environment from which the world of physics is constructed, has entered in the form of messages transmitted along the nerves to the seat of consciousness."[3] Science is founded on observation, but all of our observations are interpreted by the mind, and thus acquire a subjective nature.

At the same time Eddington was a realist, and never

surrendered his belief in an external world which is the stimulus for our observations. This objective reality is unknown by physics, but it is known by our minds. This is the ultimate reality, and it is of a spiritual, mental character.

Thus Eddington held two opposing theories of reality. It what follows we will examine how he juxtaposed these two theories without conflict.

Consciousness and Meaning

Eddington's opinion of the nature of humankind's relation to the universe provides an insight into Eddington's thought, highlighting the importance of consciousness and meaning in any discussion regarding reality.

In *Science and Religion* Eddington looks at humanity and the universe and concludes that even though we may be merely "an unfortunate incident which it seems rather ungenerous to refer to,"[4] a freak of nature, we are important, because "We are *that which asks the question.*"[5] Thus when science, which briefly put "is an attempt to set in order the facts of experience,"[6] puts forward an answer, humanity asks "Is it true?" Thus

> when from the human heart, perplexed with the mystery of existence, the cry goes up 'What is it all about?' it is no true answer to . . . reply 'It is about atoms and chaos . . . about fiery globes rolling on to impending doom . . . about tensors and non-commutative algebra.' Rather it is about a

> spirit within which truth has its shrine, with potentialities of self-fulfillment in its response to beauty and right.[7]

Truth relates to spiritual realities, to the something within us which asks the question. Eddington is clearly saying that science cannot provide us with the kind of answers we are looking for.

Consciousness, is "the first ingredient of the world of experience. . . ."[8] Science enters into the picture only after consciousness has arisen. Humanity thus enters the world of experience as a spiritual creature, and "our entry via the physical universe is a re-entry."[9] In Eddington's words

> The strange association of soul and body--of responsibility for truth with a bit of stellar matter that got cold by accident--is a problem in which we cannot but feel intense interest, but not an anxious interest as though the existence and significance of a spiritual side of experience were hanging in the balance. The solution must fit the data; we cannot alter the data to fit the alleged solution.[10]

Eddington claims that prior to the discovery of Theory of the Quantum and of Relativity Theory, science claimed to cover all of experience; however, these developments have shown that physical science is not omniscient, and as a result, there is more room for alternate explanations of reality. In fact, Eddington believes that science explains nothing. Rather it codifies and describes reality in preselected terms. The result being that if an outside observer were to gaze

upon the earth and see not a spinning globe but a ratio of two of the components of curvature in Einsteinian space-time, that observer would be "seeing truly. . . but she will be *missing the point.* It is as if we took her to a picture gallery, and she. . . . saw ten square yards of yellow paint, five of crimson, and so on."[11] The descriptions of reality that science offers are accurate and true, but they miss the meaning.

The "something to which truth matters," that "spirit within which truth has it shrine,"[12] initiates the inquiry into the nature of the physical world which we call 'science'. If that 'science' then constructs a reality which precludes spirituality, it has cut itself off at the root. Thus the "'something to which truth matters' must surely have a place in reality, if we are to use the term reality at all."[13] There must be a spiritual reality. It is primary in our experience of existence.

Having established the primacy of consciousness and the importance of meaning to Eddington, we can now turn to an examination of his thought, to see how he has interpreted modern science's statements about reality.

The Limits of Science

In an amusing story Eddington refers us to two men about to enter a room. The one is a common man and has no difficulty; the second is a physicist, and he is beset

by the seemingly insurmountable difficulty of landing on the threshold, which he knows to be composed of a few atoms but mostly of empty space, which is also travelling around the sun at an extremely high velocity, whilst he himself is in a dizzy spin, stuck head out on the revolving globe. If the question is asked which man has the "true" conception of his world, Eddington answers that it is the physicist, but that for the task at hand the truth is irrelevant. The question thus arises: When and where is scientific truth applicable?

> The question is not to be dismissed by a dogmatic classification of scientific truth as superior and commonplace truth as inferior, or of commonplace truth as practical and scientific truth as pedantic. Each has its legitimate sphere distinguished . . . by that more elusive criterion "a sense of proportion."[14]

For Eddington the question is not so much one of one truth being correct and the other incorrect, but of the appropriateness of the tool for the task at hand. When walking into a room, common sense suffices; when scrutinizing the procession of the perihelion of Mercury, relativity theory must be employed. It is of no benefit to anyone if the tools of science are indiscriminately employed for all purposes.[15]

Eddington has no use for the concept of absolute truth, especially if insisting on the absolute truth of the scientific *Weltanschauung* would require that "common sense" be replaced by it. Rather Eddington would have us

consider that

> Truth is a diamond of many facets, darting now one ray, now another, into our lives. The scientist may find the pure element within and express its essence by the precise formula of a cubic lattice--it is his business to make such analyses. But is the dull carbon to be prized higher than the radiant lustre?[16]

The scientific viewpoint is only one from among the many.

The External World

Science studies the basics of the external world, but what exactly is the external world? Eddington disparages the notion that the "external world consists of those things which really exist"[17] since we have no idea what it means to exist. For Eddington,

> The motive for the conception of an external world--a world which will remain significant when my consciousness ceases to be--lies in the existence of other conscious beings. We compare notes and we find that our experiences are not independent of one another.[18]

This common element cannot be solely in an individual consciousness, it cannot be illusion only, rather it must be placed in neutral ground--in the synthesis of the collective human consciousness--and this Eddington calls the *external world*.

The significance of this is that relativity theory is the mathematical expression of such a synthesis; it allows scientists to express in exact terms what the universe would look like from any point of view. This mathematical expression allows Eddington to draw

conclusions about the nature of the physical world which allow considerably more freedom for religious speculation than was previously possible.

Science and Truth

What kind of truth does science offer? Eddington has no use for philosophies of science in which it is held that

> the purpose of scientific theories is to provide a conception of the world which "economizes thought," and that they do not profess to represent the reality which actually exists. . . .[19]

In Eddington's opinion, scientific theories are precisely defined: they are "the common element abstracted from the experiences of individuals in all variety of physical circumstances. . . ."[20] As a result, they do not merely 'economize thought' but say something which must be either right or wrong. Science intends not to construct a world which is simple and easy to understand, but one which truthfully represents the common experiences of humankind. Thus, by definition, if we say that anything in the external world is real,

> we are merely expressing our belief that the rules have been properly followed--that it is not an hallucination belonging only to one individual experience, or a mistaken concept due to an error in the process of synthesis.[21]

Eddington feels that if something is "real" then it is part of the external world constructed according to the rules--common everyday experience. Reality is no more

than that.

Quite pragmatically, Eddington is baffled by the emphasis philosophers put on "existence" and "reality". He is sure that no one knows what this "existence" is, and is thus not afraid that the world of physics will be cancelled out of "existence" because it failed some strange metaphysical test.[22] As far as he is concerned, the external world "is the world which confronts our common experience and that therefore we are interested in knowing all we can about it."[23]

In summary, science examines the external world, the one which confronts us daily, yet the picture it creates of this world is almost unrecognizable as the common sense world. This is because it places great emphasis on the microscopic point of view. This is seen as appropriate for doing physics, but inappropriate if this viewpoint of reality is applied to philosophy and religion.

Exact Science:

To expand on why it is inappropriate to use scientific concepts and methods on all of experience, we note that Eddington refers to physics as an exact science. Eddington claims that physics is exact, not so much because of its method, but because of its chosen subject matter. That subject matter is pointer readings: we have recently realised that the claim of physics to be

an exact science is only allowable because its subject matter is much more restricted than is commonly supposed.[24] This is wonderfully illustrated in one of Eddington's unique anecdotes, one concerning a physics exam and an elephant:

> To show the kind of knowledge which physics can handle in an exact manner, let us examine critically a problem in physics such as might be set in an examination paper.
>
> The examiner, exercising his ingenuity, begins (let us say) as follows: "An elephant slides down a grassy hillside . . ." The experienced examinee knows that he need not pay heed to this; it is only a picturesque adornment to give an air of verisimilitude to the bald essentials of the problem. He reads on: "The weight of the elephant is two tons." Now we are getting down to business; henceforth the elephant can be dropped; it is "two tons" that the examinee will really have to grapple with. What exactly is this two tons--the real subject matter of the physical problem? It connotes according to some code a property, which we can only vaguely describe as *ponderosity*, occurring in a certain region of the external world. But never mind what it connotes; what *is* it? Two tons *is* the reading which the pointer indicated when the elephant was placed on a weighing-machine; it is just a pointer-reading. Similarly with the other data of our problem. The mountain flank is replaced by an angle of 60--the reading of a plumb-line against the divisions of a protector [sic]; and its verdant covering is replaced by a coefficient of friction, which though perhaps not directly a pointer-reading is of kindred nature. No doubt there are more roundabout ways used in practice for determining the weights of elephants and the slopes of hills, but they are justified because they are known to give the same results as would be obtained by direct pointer-readings. If then only pointer-readings (or their equivalents) are put into the machine of scientific calculation, how can we grind out anything but pointer-readings? But that is just what we do grind out of it. The question was, say, to find the time of descent of the elephant, and the answer is 16.5 seconds--that is to say, the difference of two pointer-readings on the seconds'-dial of our watch.[25]

Needless to say, the answer of 16.5 seconds misses out on the spectacle of the trumpeting elephant sliding through a forest into who knows what at the bottom of the hill!

After giving us this example regarding the elephant, Eddington comments that physics is in no position to handle everyday quantities such as substance, duration, extension and so forth; rather

> in its actual procedure physics studies not these inscrutable qualities, but pointer-readings which we can observe. The readings, it is true, reflect the fluctuations of the world-qualities, but our exact knowledge is of the readings, not of the qualities. The former have as much resemblance to the latter as a telephone-number has to a subscriber.[26]

This kind of knowledge is what physics provides us with. If we accept this, our image of nature and the status of physical knowledge are radically altered. It is worthwhile to quote Eddington at length on this point:

> Until recently physicists took it for granted that they had knowledge of the entities dealt with, which was of a more intimate character; and the difficulty which many find even now in accepting the theory of relativity arises from an unwillingness to give up these intuitions or traditions as to the intrinsic nature of space, time, matter, and force, and substitute for them a knowledge expressible in terms of the reading of instruments. In considering the relations of science and religion it is a very relevant fact that physics is now in course of abandoning all claim to a type of knowledge which it formerly asserted without hesitation. Moreover, these considerations indicate the limits to the sphere of exact science.[27]

Moreover, if knowledge of the external world is to encompass the responses of all objects in it to all other objects, then the methods of physics are unable to do so

when a response cannot be reduced to a pointer reading, the likableness of an elephant for example:

> This phenomenon is excluded from exact science not because of any antithesis of nature between the spiritual and the material, but because there is no pointer-reading that can stand for the "likableness" of the elephant in the way that the reading of the weighing-machine can stand for its "ponderosity."[28]

This leads Eddington to one of his greatest insights:

> I venture to say that the division of the external world into a material world and a spiritual world is superficial, and that the deep line of cleavage is between the metrical and the non-metrical aspects of the world.[29]

Thus when a metrical method is applied to a metrical subject like physics, great progress is made and there are no perceived limitations to the power of the method; when however, the method is applied to most other topics, it must be realized that important aspects of the subject will be omitted if studied in a strictly metrical fashion;[30] the *likableness* of a particular elephant in non-metrical, its *ponderosity* is metrical. Thus, it may be useful to employ metrical methods to study architecture and music, but it is obvious that in an exact numerical description of a melody and the nervous systems response to it, the numbers fail to account for the deep emotional impact of a favourite hymn. In other words, just as "there is no branch of knowledge from which exact science is wholly excluded, so it would seem that there is no branch which exact science wholly covers."[31]

The world of physics is thus restricted to those things that can be described metrically. Any other characteristics that an object of the common sense world might have is not a physical property, but a 'spiritual' one. Even such abstract concepts as potentials, force, mass and so forth, are not within the realm of physics, for they are constructs and "it appears also that the value to be attached to physical entities, such as mass and force, is . . . ultimately a value for consciousness."[32]

Thus, Eddington insists that if physics is an exact science, it is not so much because of its method, but because of the way in which it selects its subject matter. He states,

> Theoretical physics takes the form which it does take, and discovers laws of nature of a characteristic type, largely because it *chooses* to talk about these combinations of the potentials to which it has given the above names; there are other combinations which it might talk about, but it regards them as uninteresting and leaves them nameless. This choice of subject-matter made at the outset determines the nature of the super-structure. . . . It is not the basal structure but the principle of selection which plays the all important part in determining whether a law such as the conservation of energy shall take rank as a law of nature.[33]

This viewpoint could lead to total chaos, for basically what it means is that reality is what we choose it to be. There is however, a caveat, namely that only those parts of consciousness which are common to all normal individuals are to be counted as part of physical

reality. Entities which do not impinge on the normal consciousness are thus excluded from the subject matter of physics.

In summary,

> we have seen that the external world of physics is in the first place approached by way of consciousness, that it derives actuality and value from consciousness, and that it relates only to certain aspects of the common basis of material and spiritual things.[34]

It is the mind which constructs the permanent world.

> When the eye surveys the tossing waters of the ocean, the eddying particles of water leave little impression; it is the waves that strike the attention, because they have a certain degree of permanence. The motion particularly noticed is the motion of the wave form, which is not a motion of the water at all. So the mind surveying the world of point-events looks for the permanent things.[35]

By selecting only the permanent things in the world, the mind constructs reality out of perceived relations and erects structures that give *form* to the external world without knowledge of its actual *content*. In Eddington's words

> Our whole theory has really been a discussion of the most general way in which permanent substance can be built up out of relations; and it is the mind which, by insisting on regarding only the things that are permanent, has actually imposed these laws on an indifferent world. Nature had very little to do with the matter; she had to provide a basis--point-events, but practically anything would do for that purpose if the relations were of a reasonable degree of complexity. . . . that is to say, it is structure, not material which counts.[36]

The world of physics consists only of structure, devoid of content. Now this is not to say that there is nothing in

the external world, that the structures of the external world are constructed out of nothing; there is an underlying reality. However, this underlying reality is unknown to us, and it is only by the efforts of our minds that we can see our familiar, everyday world. Further, this underlying reality's exact nature is in fact irrelevant, needing to be only "point-events" of sufficient complexity, so that "practically anything would do." It is not the nature of the underlying reality, but the nature of our own make-up that determines the structure of the physical world. Thus Eddington speculates that it is mind which

> filters out matter from the meaningless jumble of quantities . . . it exalts the permanent and ignores the transitory. . . . Is it too much to say that the mind's search for permanence has created the world of physics?[37]

Eddington acknowledges that the "last sentence possibly goes too far. . ."[38] but thinks that it does illustrate "the direction in which these views are tending."[39]

There is an underlying reality. This can not be denied. But it is not this underlying reality that physics studies. Physics studies the external world as it is presented to us after we have received the sensory data and processed it; physics studies the contents of our collective subjective consciousness. As far as the actual nature of things is concerned, "this knowledge is only an empty shell--a form of symbols."[40]

CHAPTER FOUR

Eddington the Quaker

> The Father uttered one word and that word was his Son, and He utters it everlastingly in silence and in silence a soul has to hear it.[1]

Having surveyed Eddington's exposition of his philosophy of science, and seen that he has essentially two distinct concepts of reality--physical reality as a construction of mind, which is studied by science; and "real" reality as that which underlies all that is, an unknowable foundation--some explanation of how Eddington could hold these two concepts of reality at the same time is required. The present chapter will show that it is Eddington's religious convictions as a Quaker that provide an explanation for his faith in a foundational reality, and that only by understanding the primary position that *religious experience* has in Eddington's thought can his two views of reality be harmonized.

It has been recognized that one "of the most powerful factors in the formation of Eddington's intellectual outlook and spiritual perceptivity was the Quaker

atmosphere of his home. . . . "[2] The Quaker way of life--which is built around the silent communion of their meetings, where, sitting in a circle they experience God in the silence of meditation[3]--cannot but have predisposed Eddington to quiet contemplation of the mysteries of the universe, and sensitized him to its mystical qualities.

This is not to say that sensitivity to inward experiences caused him to depreciate scientific reason; indeed, his Quakerism seems to have stimulated research not only into the interior life, but in all of nature. In this he respect Eddington was like many other Quakers, for they "are said to have had more members in the Royal Society than did any other religious group."[4]

Eddington certainly seems to have enjoyed communion with God in the Society of Friends, and enjoyed an appreciation of God as revealed in nature. Since such experiences were not unusual for Eddington,[5] they most certainly could not be excluded from his conception of reality. Indeed, the primacy of these personal experiences makes it impossible for Eddington to accept the "decrees of science with an anxious interest as though the existence and significance of a spiritual side of experience were hanging in the balance. The solution must fit the data; we cannot alter the data to fit the alleged solution."[6]

For Eddington, "observation is the High Court of Appeal" and the "only subject presented to me for study is the content of my consciousness;"[7] the awareness of God's presence--which occurs not merely in the consciousnesses of deranged individuals but within entire groups of sane citizens such as the Society of Friends--is a primary fact. As a result, any comprehensive philosophy must be able to account for religious experience. This basic premise reflects, as the Quaker scholar Douglas V. Steere says, the "profound grasp of the relation of intuition and reason which in no generation of Quakerism has ever been entirely absent."[8]

Rufus M. Jones, the well known Quaker, philosopher, and contemporary of Eddington's, confessed that it was a small group of Quakers that gave him the spiritual depth that allowed him to keep his faith without "preventing me from making use of all that science and history have revealed. . . ."[9] Quakerism's appreciation of the inward experience thus in no way challenges science's claims to truth concerning the external world, but it does reveal that science does not have a handle on absolute truth.

Eddington emphasizes the need for an adequate world-view to account for all of human experience, to account for the *selves* to whom truth matters. He reminds us that it

> was by looking into our own nature that we revealed the first failure of the physical universe to be co-

> extensive with our experience of reality. The 'something to which truth matters' must surely have a place in reality, if we are to use the term reality at all. In our own nature, or through the contact of our consciousness with a nature transcending ours, there are other things that claim the same kind of recognition--a sense of beauty, of morality, and finally at the root of all spiritual religion an experience which we describe as the presence of God.[10]

What Eddington means is that if the physical universe is a world of pointer readings which by definition excludes the subjective elements of reality, it is incomplete. If consciousness is the only thing we are aware of, then objective reality is best identified "with the conscious and spiritual aspects of experience;"[11] the experiences traditionally derided as "subjective" are regarded by Eddington as primary. Thus, when the physical universe fails to account--by definition--for spiritual reality, it has failed to be co-extensive with our experience of reality. Since the whole quest of science is launched by that within us to which truth matters, science should at least acknowledge that this force within is a valid part of human experience; if it cannot do so, it is not an adequate philosophy. This is again a fundamental axiom of Quakerism; as Isaac Penington wrote, "For reason is not sin, but a turning from that which reason came is sin."[12] An adequate philosophy must be able to account for inward experience.[13]

The importance of inward, mystical experiences for

Eddington can clearly be seen in his appreciation of nature. He refers us to a description of such an experience as given by J. S. Hoylands, who said:

> There is an hour of the Indian night, a little before the first glimmer of dawn, when the stars are unbelievably clear and close. . . . the whole world seems to be intent, alive, listening, eager. At such times the veil between the things that are seen and the things that are unseen become so thin as to interpose scarcely any barrier at all between the eternal beauty and truth and the soul which would comprehend them.[14]

Regarding this experience Eddington goes on to say

> Here is an experience which the 'observer' as technically defined in scientific theory knows nothing of. The measuring appliances which he reads declare that the stars are just as remote as they always have been, nor can he find any excuse in his measure for the mystic thought which has taken possession of the mind and dominated the sense-impressions. Yet who does not prize these moments that reveal to us the poetry of existence? We do not ask whether philosophy can justify such an outlook on nature. Rather our system of philosophy is itself on trial; it must stand or fall according as it is broad enough to find room for this experience as an element of life.[15]

Eddington is saying here that the "poetry of existence" is an outlook on life which requires no justification. The reality of the experience is indisputable. To emphasize this point, he relates two times when he was interested in the motion of waves. On the first occasion he consulted Horace Lamb's *Hydrodynamics*, but on the second occasion, he consulted the poet Rupert Brooke and read:

> There are waters blown by changing winds to laughter
> And lit by the rich skies, all day. And after,
> Frost, with a gesture, stays the waves that dance
> And wandering loveliness. He leaves a white
> Unbroken glory, a gathered radiance,
> A width, a shining peace, under the night.[16]

To this Eddington comments:

> The magic words bring back the scene. Again we feel Nature drawing close to us, uniting with us, till we are filled with the gladness of the waves dancing in the sunshine, with the awe of the moonlight on the frozen lake. These were not moments when we fell below ourselves. We do not look back on them and say, 'It was disgraceful for a man with six sober senses and a scientific understanding to let himself be deluded in that way. I will take Lamb's *Hydrodynamics* with me next time.' It is good that there should be such moments for us. Life would be stunted and narrow if we could feel no significance in the world around us beyond that which can be weighed and measured with the tools of the physicist or described by the metrical symbols of the mathematician. . . .[17]

Clearly experiences which can be loosely defined as "mystical" are of great importance--not only to Eddington, but to all human beings. Equally clear is that these experiences cannot be evaluated by empirical measurements, yet are precisely those which make us into human beings. The physical world, as described by Eddington, requires only that humans act as measuring devices; yet it is obvious to Eddington that the mystical experience reveals that there is more to reality than the world of physics contains.

Recognizing that the religious experience is real, and not a mere delusion that is somehow inferior to pure science, Eddington asks rhetorically:

> 'Are we, in pursuing the mystical outlook, facing the hard facts of experience?' Surely we are. I think that those who would wish to take cognizance of nothing but the measurements of the scientific world made by our sense-organs are shirking one of the most immediate facts of experience, namely that consciousness is not wholly, nor even primarily a device for receiving sense-impressions.[18]

In other words, as conscious beings our consciousness relates to reality in diverse ways, not just to the restricted set of measurable quantities. To deny the experience of pain, pleasure, and humour is to deny vast parts of our experience of reality.

The human mind is not restricted to receiving sense-impressions; it is open to the divine mind. Quaker scholar Caroline Stephen states quite clearly the Quaker belief that "the direct influence of the divine mind upon our own. . ." [is] the primary Guide in the voyage of life. . . ;"[19] consciousness is for receiving the thoughts of God. In contrast, Eddington is very cautious on this point and merely speculates that if light and colour and sound come into our minds from outside of ourselves, is it not possible that the "stirrings of consciousness come from something which. . . . is wider than our individual personality?"[20]

In Eddington's opinion, even if the mind's direct contact with God in mystical experience cannot be proven, a philosophy which cannot accommodate the subjective aspects of human experience is deficient. As anyone who has ever laughed at a joke cannot deny, the experience of

humour is very real, and Eddington makes a salient point when he compares the experience of humour with the mystical experience of God. He says,

> There are some to whom the sense of a divine presence irradiating the soul is one of the most obvious things of experience. In their view a man without this sense is to be regarded as we regard a man without a sense of humour. The absence is a kind of mental deficiency. We may try to analyse the experience as we analyse humour, and construct a theology, or it may be an atheistic philosophy, which shall put into scientific form what is to be inferred about it. But let us not forget that the theology is symbolic knowledge whereas the experience is intimate knowledge. And as laughter cannot be compelled by the scientific exposition of the structure of a joke, so a philosophic discussion of the attributes of God (or an impersonal substitute) is likely to miss the intimate response of the spirit which is the central point of the religious experience.[21]

Once again Eddington emphasizes the experiential nature of mystical awareness; it is "intimate knowledge"--the primary content of consciousness. Steere describes Quaker meetings as "laboratories of the Holy Spirit where Jesus Christ fulfilled his promise that 'where two or three are gathered in my name, there I am in the midst of them.'"[22] Quaker meetings are experiences in which the seeker is advised to "Be still, and wait for light and strength, and desire not to know or comprehend, but to be known and comprehended in the love and life, which seeks out, gathers, and preserves lost sheep."[23]

Mystical experience is direct and unmediated. In contrast, scientific exposition is "symbolic knowledge," a system of shadow realities. The primacy of the

mystical experience precludes any denial of its reality by reasoned argument; and of course science has no authority to deny the validity of such experience, for by definition science deals only with pointer readings, with things that can be broken down into measurable quantities. Thus Eddington concludes that

> If we claim that the experience which comes to us in our silent meetings is one of the precious elements that make up the fullness of life, I do not see how science can gainsay us. Let it [science] pause before rushing in to apply a supposed scientific test; for such a test would go much too far, stripping away from our lives not only our religion but all our feelings which do not belong to the function of a measuring-machine.[24]

In short, science analyzes only one aspect of our reality, which Eddington has described as the physical world. The physical world is not all encompassing; it fails to take into account all the 'subjective' aspects of experience, since it is by definition a collection of pointer readings, of metrical values. Since the sciences which create and study the physical world are self-limited in scope, they are unable to account for those aspects of experience which Eddington considers primary, namely those impinging directly on our consciousnesses. This is also the position taken by the early Quaker writer, Isaac Penington (1616-1679), who emphasized the inward nature of true knowledge. He says we should distinguish "between words *without* concerning the thing, and the thing itself *within*; and wait and labour then to

know. . . the thing itself within."[25] True knowledge is intuitive and inward. True knowledge places far more value on intuitive, inward knowledge of a thing, than on empirical data concerning it.

Eddington sees the mystical experience as the primary method for apprehending a comprehensive picture of reality. Though reluctant to do so, Eddington summarizes the import of the mystic experience as follows:

> If I were to try to put into words the essential truth revealed in the mystic experience, it would be that our minds are not apart from the world; and the feelings that we have of gladness and melancholy and our yet deeper feelings are not of ourselves alone, but are glimpses of a reality transcending the narrow limits of our particular consciousness--that the harmony and beauty of the face of Nature is at root one with the gladness that transfigures the face of man. We try to express much the same truth when we say the physical entities are only an extract of pointer readings and beneath them is a nature contiguous with our own. But I do not willingly put it into words or subject it to introspection. We have seen how in the physical world the meaning is greatly changed when we contemplate it as surveyed from without instead of, as it essentially must be, from within. By introspection we drag out the truth for external survey; but in the mystical feeling the truth is apprehended from within and is, as it should be, a part of ourselves.[26]

Eddington here displays typical Quaker reticence at discussing mystical experience; "Quakers find it hard not to look with suspicion on talk about the interior life and about the practices that nurture it."[27] Rather than attempt to prove the validity of mystical experience, Eddington prefers to show that traditional science is

unable to disprove inward experiences, allowing these experiences to be appreciated in their own right, without recourse to scientific critique or explanation.

This is not to say that the mystical insight provides all of the answers to humanity's problems; just as science is unable to speak to issues which interest us intensely as human beings with subjective experiences, just so the mystical experience cannot answer empirical problems. Eddington felt that the apprehension of spiritual truths could not be derived from scientific conclusions, and that there was no one-to-one correspondence between "objects" in the external world and the "subject" in our consciousnesses. The relationship between the mystical world and the physical world is more complex. Very briefly, Eddington explains the relationship as follows:

> I contemplate a spiritual domain underlying the physical world as a whole, [but] I do not think of it as distributed so that to each element of time and space there is a corresponding portion of the spiritual background. My conclusion is that, although for the most part our inquiry into the problem of experience ends in a veil of symbols, there is an immediate knowledge in the minds of conscious beings which lifts the veil in places; and what we discern through these openings is of mental and spiritual nature. Elsewhere we see no more than the veil.[28]

Regarding that which is beyond the veil nothing can be said, but, in the silence of the soul, it can be heard.

Conclusion

This thesis has attempted to expose the thoughts of Eddington on the notion of reality to fresh analysis. In doing so, it has put Eddington into the context of Cambridge at the turn of the century, as a person formed by a Quaker upbringing and convictions, in a scientific community in the process of general upheaval brought on by Einstein's Theory of Relativity and by the Theory of the Quantum. Eddington brought diverse factors together in his philosophy of physical science, creating a philosophy which reflects his milieu, but also some unique features which can only be attributed to his Quakerism.

Eddington's approach involves showing that contemporary science's description of the physical world is not so much an accurate reproduction of what is actually out there, but only a description of a small portion of the reality subjectively created by the mind. Like Kant,[1] Eddington believes our intellectual and sensory equipment determines *a priori* what our physical world will be like. The physical world which science studies is therefore subjective. Eddington describes how science studies the self-contained world of physics

which, for all of its knowledge, *by definition* can never deal with the larger world of human emotion, or with questions of meaning.

Eddington feels that there is a spiritual substratum which can be said to be real. This substratum is experienced when we glimpse the beauty of nature, or apprehend the presence of God in silent meditation. It is experienced by all people before our minds begin to analyze and comprehend what it is that we have experienced. It is essentially, everything; however, it is ineffable.

In terms of what this study has done and what remains to be done, the materials and method of presentation were limited by necessity to Eddington's philosophical works and only cursory comparisons to Eddington's contemporaries. Perhaps the most fruitful endeavor which could follow this study would involve more detailed comparisons between Kant and Eddington. While such a study has been undertaken by Witt-Hansen, this excellent work failed to see how the pivotal place which Eddington's mysticism had in his philosophy allowed Eddington to simultaneously have a realist and a phenomenological ontology. A more detailed study could also have incorporated an in depth comparison between the philosophies of Eddington and his contemporaries, such as Heisenberg, but who did not share his Quaker upbringing.

Such a comparison would further highlight the impact that Eddington's mystical beliefs had on his philosophy. Alternately, it would be interesting to compare Eddington to Schrödinger and determine how their respective religious persuasions influenced their philosophies.

On the other hand, other approaches to Eddington's thought which would supplement this thesis in very different ways are also conceivable. One intriguing approach would be to examine the mathematical foundations for Eddington's philosophical claims, balancing his established integrity as an astrophysicist, astronomer and theoretical physicist against his philosophical proposals. What is the significance of Eddington's calculations of universal constants, such as the cosmical number--$2 \times 136 \times 2^{256}$--the total number of protons and electrons in the universe?[22] Or of the fine structure constant, whose value he determined to be 137, and which experimentation is repeatedly verifying?[23] Sir Edmund Whittaker has examined Eddington's calculations, but has only hinted at their possible implications for philosophy.

Finally, Eddington has raised an important question, unique in its setting but not new in the wider context of the dialogue between science and religion; what is the relationship between epistemology and ontology? By approaching the world from an epistemological perspective

Eddington was able to relegate physics to a mere description of what we *can* perceive; physics is phenomenologically oriented. In contrast, the mystical experience supposedly bypasses our analytical minds and provides direct insight into reality. The question raised by Eddington regarding the status of scientific knowledge and religious-mystical knowledge is one that will most certainly require further study if we are to come to a fuller understanding of the nature of reality.

ENDNOTES

Introduction

[1] Vibert A. Douglas, *The Life of Arthur Stanley Eddington.* (London: Thomas Nelson and Sons, Ltd., 1957) 133

[2] J. G. Crowther, *British Scientists of the Twentieth Century* (London: Routledge & Kegan Paul, Ltd., 1952) 188

[3] Donald B. Marquis, "In Defense of Sir Arthur Eddington" *Southwestern Journal of Philosophy* 7 (1976) 138

[4] A. S. Eddington, *Science and the Unseen World*, (London: George Allen & Unwin, 1929) 45

[5] A. S. Eddington, "The Domain of Physical Science," in *Science, Religion and Reality*, Ed by Joseph Needham, (New York: George Braziller, Inc., 1955) 221

Chapter One

[1] Albert Einstein, *The World as I See It.* Translated by Alan Harris. (London: The Bodley Head, 1935) 27

[2] PPS, 54

[3] By *physical* reality Eddington means the reality with which physics deals. It bears only accidental resemblance to the common sense world of concrete objects.

[4] Information regarding Eddington in this section comes mainly from two sources: Vibert A. Douglas, *The Life of Arthur Stanley Eddington* (London: Thomas Nelson and Sons Ltd., 1957); and J. G. Crowther, *British Scientists of the Twentieth Century* (London: Routledge & Kegan Paul, Ltd., 1952), pages 140-196.

[5] The senior Wrangler is the student with the highest grades in the Mathematical Tripos (exams) for that year.

[6] Crowther, 148

[7] Crowther, 142

[8] Crowther, 148

[9] Crowther, 144

[10] Crowther, 143

[11] He was asked to expand a pamphlet for the Cavendish Laboratory which he had previously written. He refused, since adding to "it would be to add a new part to a finished picture. He regarded his expostions as harmonious works of art, and he made them so." Crowther, 144

[12] By the noted astronomer, Harlow Shapely, as quoted in Crowther, 144

[13] Crowther, 141, 163

[14] Crowther, 141

[15] quoted in Crowther, 153-54

[16] This was apparently the attitude of the French, who even several years after the war refused to consider the theory because of nationalistic passions. Crowther, 154

[17] Among the honours awarded to Eddington were the Gold Medal of the Royal Astronomical Society in 1924, and the Royal Medal of the Royal Society in 1928. He was president of the former society in 1921-23 and of the Physical Society in 1930-32. He was elected president of the International Astronomical Union in 1938 and awarded many honorary degrees. He was knighted in 1930 and received the Order of Merit in 1938.

[18] Max Planck, *Where is Science Going?* (London: George Allen & Unwin, 1933) 218

[19] Planck, Quoted in Ilse Rosenthal-Schneider, *Reality and Scientific Truth*, (Detroit: Wayne State UP, 1980) 71, from *Wissenschaftliche Selbstbiograpie* (Leipzig: n.p., 1948) Translated by F. Gaynor as *Scientific Biography and Other Papers* (New York: n.p., 1949) 13

[20] Werner Heisenberg, *Physics and Philosophy* (London: 1958) 129

[21] James Jeans, *The Mysterious Universe.* (Cambridge: UP, 1948) 127

[22] PPS, 216

[23] Jeans, *Mysterious*, 125. cf. Eddington: "The only subject presented to me for study is the content of my consciousness." NPW, 283

[24] De Broglie, *Physics and Microphysics.* (NY: Pantheon, 1955) as quoted in Ken Wilbur, *Quantum Questions*, (Shambhala: New Science Library, 1984) 119

[25] Einstein, *Ideas and Opinions.* (NY: Crown Pub., 1954) as quoted in *Quantum Questions*, 107. Emphasis mine.

[26] Schrödinger, quoted in *Quantum Questions*, 79.

[27] Jeans, *Mysterious*, 130

[28] Jeans, *Mysterious*, 137

[29] Rosenthal-Schneider, *Reality*, 38. She is summarizing Einstein.

[30] Rosenthal-Schneider, *Reality*, 53

[31] One gets the impression from Rosenthal-Schneider that Einstein was opposed to the Copenhagen interpretation of the Theory of the Quantum because he thought that quantum theory reveals more than knowledge about observables, that it describes reality. I am not so sure. I believe that he was opposed to the Copenhagen interpretation, not because of the limits which it puts on what quantum theory can tell us about what we observe, but to the *reduction* of *reality* to that which we can observe. For him, reality was much more than that.

[32] Not that any definition of reality in science exists, but it has often been assumed that scientists *knew* what reality was.

[32] Rosenthal-Schneider, *Reality*, 74. From an interview with Einstein.

[33] A. Einstein, "Remarks on Bertrand Russell's Theory of Knowledge" in *The Philosophy of Bertrand Russell.* Edited and translated by Paul Arthur Schilpp. (New York: Harper & Row, 1963) 287

[34] Rosenthal-Schneider, *Reality*, 83

[35] Rosenthal-Schneider, *Reality*, 15, 18

[36] Rosenthal-Schneider, *Reality*, 42 n9

[37] Rosenthal-Schneider, *Reality*, 27. Quoting a comment Einstein made in 1949.

[38] For Rosenthal-Schneider the construction of a world view is "essential", *Reality*, 65f

[39] Einstein to Bohr in 1949. Quoted by Arthur I. Miller in the foreword to Rosenthal-Schneider, *Reality*, 21

[40] It is interesting to note that Pauli was acutely aware of the need to de-throne the Kantian absolutes. Heisenberg makes this comment on Pauli's attitude towards Kant's a priori:

> The Kantian employment of the a *priori* concept he criticizes in very decided terms, since Kant had used this expression for rationally fixable forms of intuition or forms of thought. He expressly warns that 'one should never declare theses laid down by rational formulation to be the only possible presuppositions of human reason.' Pauli, on the contrary, brings the a *priori* elements of natural science into intimate connection with the primeval images, the archetypes of Jungian psychology, which do not necessarily have to be regarded as innate but may be slowly variable and relative to a given cognitive situation.

Heisenberg, on Pauli, quoted in *Quantum Questions*, 162

[41] From Ilse Rosenthal-Schneider, *Reality and Scientific Truth: Discussions with Einstein, von Laue, and Planck.* (Detroit: Wayne State UP, 1980) 89

[42] NPW, 254

[43] "Whenever we state the properties of a body in terms of physical quantities we are imparting knowledge as to the response of various metrical indicators to its presence, *and nothing more*." NPW, 257

[44] NPW, 270ff

[45] Immanuel Kant. *Prolegomena to any future metaphysics that will be able to come forward as science.* The Paul Carus translation, extensively revised by James W. Ellington. (Indianapolis: Hackett Pub. Co., 1977) Remark II

[46] *Prolegomena*, §38

[47] *Prolegomena*, §36

[48] PPS, 1,3

[49] PPS, 116

[50] W. Heisenberg, quoted in *Quantum Questions*, 73

[51] E. Schrödinger, quoted in *Quantum Questions*, 81

[52] NPW, 158

[53] NPW, 159

[54] Jeans, *Mysterious*, 123

[55] *Prolegomena*, Remark II

[56] Schrödinger, quoted in *Quantum Questions*, 92. Schrödinger is quick to point out that what he is saying is not blasphemous nor lunatic, but merely a restatement of the ancient truth "ATMAN=BRAHMAN" Schrödinger has clearly been influenced by the Vedantic tradition, and his interpretation of it and modern science is most illuminating, but beyond the scope of this thesis.

[57] Schrödinger, quoted in *Quantum Questions*, 84

[58] Jeans, *Mysterious*, 127

[59] Schrödinger, quoted in *Quantum Questions*, 84

[60] NPW, 283f. I will take the opportunity here to point to some of the possible Kantian influences on Eddington's thought. In the *Prolegomena* Kant states that he is concerned "only with the knowledge of nature, the actuality of which can be confirmed by experience, though this knowledge is possible *a priori* and precedes all experience." (*Prolegomena* § 16) Kant does not attempt to prove that knowledge of nature is possible *a priori*, but assumes it. He posits that we do have experiences of nature, and that we have codified these experiences under a system of universal laws. The propositions 'substance is permanent,' or 'every event is determined by a cause according to constant laws,' "are actually universal laws of nature, which hold completely *a priori*." (*Prolegomena* § 15) Further, he says:

> nature. . . considered as the totality of appearances, [is] possible. . . . By means of the constitution of

> our sensibility. . . which. . . is. . . affected by objects which are in themselves unknown to it and totally distinct from those appearances. (*Prolegomena* § 36)

Thus it is the way in which our perceptions function, affected by external objects, which conditions the way in which we construct nature to fit our perceptions. Further, regarding the mind Kant says

> nature [is] possible. . . . by means of the constitution of our understanding, according to which all. . . representations of the sensibility are necessarily referred to a consciousness, and by which the peculiar way in which we think (namely, by rules) and hence experience also are possible, but must be clearly distinguished from an insight into the objects themselves. (*Prolegomena* § 36)

In short, our senses represent something to our consciousness, which then assembles it all under a system of rules, calling the result, nature. But Kant is clearly saying that these laws that we know are not the laws that govern *things in themselves*; rather only our experience of *appearances*. This is possible because "the principles of possible experience are ... at the same time universal laws of nature, which can be known a *priori*." (*Prolegomena* § 23)

How do we know nature? First we perceive *appearances*, and the mind organizes these representations, and makes 'judgments of perception' based on them, but these judgments are valid only for us personally. If we compare our judgments of perception with similar judgments in other consciousnesses, and find that these overlap, our mind (understanding) posits that these judgments are universal, and organizes them into 'judgments of experience' which are valid for all minds.

> The result of this organization is *nature* which is 'phenomena under laws' given by the understanding. These laws, necessary for there to be any objective (that is, intersubjective) experience, are not *derived* from any experience, but are *a priori* functions or rules of the understanding which *apply* to all our experience. (*Prolegomena*, from the editor's introduction, xvi)

Thus "the objective validity of the judgment of experience signifies nothing else than its necessary universal validity. . . ." (*Prolegomena* § 18) Kant summarizes as follows:

> Therefore objective validity and necessary universality . . . are equivalent terms, and though we do not know the object in itself, yet when we consider a judgment as universal. . . we. . . understand it to have objective validity. (*Prolegomena* § 19)

It is "by the universal and necessary connection of the given perceptions" (*Prolegomena* § 19) that we know the object, though it remains completely unknown to us as it really is. In other words, objectivity is merely universal subjectivity. (*Prolegomena* § 17)

Kant is trying to make clear that what makes our experience knowledge of *objects* is its "conformity to certain rules which are not rules of private association, but rules of synthesis for any consciousness whatever. . . ." (*Prolegomena*, from the editor's introduction, xvi, n 10)

Nature has objectivity because its appearance in many consciousnesses has a uniform, lawlike, regularity. Its objectivity has little to do with whether it is "kickable", but with its coherent organization within human consciousness. Thus when Kant is talking about objective nature, he is still only referring to the sum total of *appearances*.

[61] Jeans, *Mysterious*, 111

[62] Wilber, *Quantum Questions*, 7

[63] Wilber, *Quantum Questions*, 7-8

Chapter Two

[1] NPW, 285. The "loud cheers" which Eddington refers to in this quote are those which supposedly would be given to anyone who uses the term reality "*with the intention of evoking sentiment.*" NPW, 283. He is being derisive of those who claim to know what is meant by "reality" and who use it in grand peroration. He feels that the difficulty is not so much with using the term "reality" but with "reality (loud cheers)"; that is, with the purpose of evoking sentiment. For Eddington, reality in science is something totally lacking sentiment, and for him a "thing may be said to be real if it is the goal of a type of inquiry to which I personally attach importance." NPW, 283. In this context, the reference to "reality (loud cheers)" is meant to say that the truth which science seeks is merely a matter of definition, the "goal of a type of inquiry", and no more.

[2] ST&G, 182

[3] ST&G, 10

[4] A. S. Eddington, *The Mathematical Theory of Relativity*, (Cambridge: UP,1923), 238

[5] PPS, 159. This thesis is in general an attempt to clarify Eddington's use of the terms reality, physical world, world of physics and spiritual world and their relationships to each other. But in order to obviate confusion, I will attempt to give some brief definitions here.

According to Eddington's usage, the *physical world* and the *world of physics* are synonomous. Since Eddington is saying throughout his philosophy that the world of physics is merely a construct, this strongly implies that what we normally call "the world" or the "physical world" is no more than a construct. This is not accidental for he intends to say that.

The *underlying reality* and the *spiritual world* are also synonomous, indicating that mystical awareness is awareness of reality as no other experience can be.

Reality is used in context, but usually is used to refer to common sense reality, the everyday world.

As to the relationships between these realities, the *underlying reality* informs the *physical world* and common sense reality. Yet there is no necessary relationship between any one "object" in the *physical world* and something in the *underlying reality*. The difference between the common sense *reality* and the *physical world* is that the former contains far more that the latter, since it encompasses all of human emotion as well as strictly metrical quantities. The *physical world* though, is a far more rigourous structure of constructs than ordinary *reality* is.

[6] PPS, 209

[7] PPS, 111

[8] "I hope it is now sufficiently clear that I repudiate any metaphysical concept of 'real existence'; and I may without danger introduce a *structural concept of existence* which has a mathematically defined sense." PPS, 162

[9] PPS, 198. cf PPS 217 where he insists that the commonality of the content of our consciousness is not due to circumstance, but is based on the objective content of the external world which informs our observations thereof.

[10] DPS, 231

[11] DPS, 214

[12] DPS, 214

[13] DPS, 215

[14] The casual use of terminology is a problem in Eddington's writing; it is a characteristic of Eddington's which makes him easy to understand for the uncritical reader, but frustrating for the analyst attempting to get at the real meaning of his philosophy. I have attempted to ignore these inaccuracies in much the same way that Eddington has, striving instead to get at the central concepts in his philosophy.

[15] Unfortnately, Eddington's casual use of terminology results in some unclarity here. The difficulty lies in the use of the phrase "the physical world. . . impinges upon the spiritual world. . . ." Taken literally, this contradicts a great deal of Eddington's philosophy. If I have interpreted Eddington correctly, I would think that he should have said that the "spiritual world impinges upon our minds, and the physical world is the result". This view is represented in Eddington's *New Pathways in Science*, (Cambridge: UP, 1935) 322, and is partially quoted on page 84 of this thesis.

[16] DPS, 207-213

[17] DPS, 216

[18] Alternately, consciousness constructs physical reality from certain characteristics of the underlying reality. The choice of words here, between selection and construction, is not only a matter of semantics, even though Eddington could have used either term. The choice of terms depends on the emphasis, and on the area of human thought under consideration. Thus If *select* is employed, more emphasis must be placed on the fact that it is the mind which selects, and selects according to the physical and intellectual make-up of the human being concerned. If *constructs* is employed, then the subjective character is already emphasized, and it must be remembered that all we objectively know is the contents of our own consciousnesses; the construction of our own realities in no way reduces the "reality" of the underlying foundation of which we know nothing for certain.

More importantly, the domain of thought under consideration must be taken into account. Eddington himself refers to his philosophy as "selective

subjectivism", and admits that selection implies something to select from. That something is the underlying reality. The mind selects certain characteristics from the underlying reality and recognizes these as "real"; which characteristics it selects depending on human physical and psychological make-up. Science then *constructs* a system of thought based on these selections, and studies that system of thought, or at best the selections; but is does not study the underlying reality.

Again, in no way does Eddington wish to say that consciousness itself constructs the underlying reality; rather, consciousness constructs its reality from characteristics given in the underlying reality.

[19] *Prolegomena* § 18

[20] DPS, 217. cf. ST&G, 196-98 where Eddington discusses permanence as a feature of the mind.

[21] DPS, 218

[22] ST&G, 198

[23] Eddington, "Evening Discourse to the British Association at Oxford, 1926" quoted in Crowther, *British Scientists*, 175-176

[24] "The frank realization that physical science is concerned with a world of shadows is one of the most significant of recent advances." NPW, xv

[25] ST&G, 200.

[26] A. S. Eddington, *New Pathways in Science* (Cambridge: UP, 1935) 292. cf PPS, 216: "I have emphasized two features of the knowledge of the external world reached in this way [based on sensation]: (a) it is partly subjective, and (b) it is structural knowledge."

[27] PPS, 87

[28] There is some confusion in regards to what Eddington means by the *subjectivity* of the physical world; especially because he sometimes uses *partially* subjective and implies *wholly* subjective elsewhere. I think what he means is that if we recognize the underlying reality, and its influence on the spiritual aspect of humans, then physical reality is only partially subjective. If we do not recognize consciousness and its awareness of something "more"--as science does not in his description of it--then the physical world is wholly subjective.

This would be my interpretation of Eddington; for comparison to Eddington's own thoughts, see his discussion about the circular nature of scientific thought as developed in his analogy based on "the house that Jack built" in NPW, 260-272.

[29] ST&G, 201

[30] Eddington's 'Two Tables" analogy has generated considerable discussion. See especially those by L. S. Stebbing, "The Furniture of the Earth", in *Philosophy of Science* Eds. Arthur Danto and Sidney Morgenbesser. (New York: World Pub. Co./Meridian Books, 1960) 69-81, and by James W. Cornman, "Can Eddington's 'Two' Tables be Identical?" *Australasian Journal of Philosphy* 52 (1974) 22-38. It is interesting to note the distance that this idea has come; in Eddington's time it was a very radical point of view, now, it is almost accepted as common sense. For example, Lawrence Leshan and Henry Margenau in *Einstein's Space & Van Gogh's Sky* (New York: Collier Books, 1982) write "This distinction between the two desks is perfectly correct." and "In a strict sense the desk is a creation of our minds." 48-49. It would be interesting to pursue the idea of multiple truths in relation to Madhyamika Buddhism's Non-dualistic doctrine of reality, where the self is assumed to exist as undifferentiated consciousness, and the object-world is seen as dependent on this consciousness. The world is not seen to be non-existent, but dependent on consciousness.

[31] NPW, ix-xii

[32] As was shown in the first chapter, Einstein--and others--thought that a belief in the reality of nature was essential to doing physics. Eddington himself says: "The physicist, so long as he thinks as a physicist, has a definite belief in a real world outside him." ST&G, 180

[33] John W. Yolton, *The Philosophy of Science of A. S. Eddington* (The Hague: Martinus Nijhoff, 1960) is of the opinion that Eddington vacillated between an operationalist and realist ontology. While Yolton's work is excellent, I find that his conclusion that Eddington was at root a realist both true and yet misleading. It depends on what you mean by reality. Yolton seems to think that Eddington had a grip on reality--that you can't be a realist without having reality immediately before your senses. This is clearly not Eddington. Eddington was a realist in the sense that he did not deny the existence of an underlying reality; however, that

reality is not able to be brought before our senses--it is ineffable. If anything, Eddington thought that science collapses epistemology and ontology. See Yolton, esp, 109-126.

[34] PPS, 209 Compare this to Kant, who thought that the sensuous world is nothing but a chain of appearances connected according to universal laws, neither of which have subsistence by themselves. This world of appearances must "point to that which contains the basis of this appearance, to beings which cannot be known merely as appearances, but as things in themselves. In the knowledge of them alone can reason hope to satisfy its desire for completeness in proceeding from the conditioned to its conditions." (*Prolegomena* § 57) Where Kant assumes the *necessity* of some objective thing in itself to unify the appearances, Eddington merely posits that objectivity is collective subjectivity. Eddington does assume an underlying reality, however, this is based on mystical *experience* of it, not on its logical necessity.

[35] NPW, 284

[36] ST&G, 46, 59, 70, 107, 199. On these pages Eddington discusses the various apparently universal constants.

[37] ST&G, 9

[38] NPW, 283-84. Cf. Russell's views, as expressed primarily in *The Analysis of Matter*. An excellent review of Russell, Eddington and Jeans appears in C.E.M. Joad, *Philosophical Aspects of Modern Science*. London: George Allen & Unwin, 1932.

[39] PPS, 26

[40] ST&G, 35

[41] ST&G, 87

[42] ST&G, 182

[43] NPW, 284

[44] NPW, 291

[45] On relations, and the content of the physical world as the content of our minds, see NPW, 276-282; PPS, 164

[46] NPW, 291

[47] NPW, 292

[48] NPW, 101

[49] PPS, 197-98

[50] NPW, 98

[51] NPW, 91

[52] NPW, 97

[53] NPW, 92-94 Time is an intrinsic property of the four-dimensional fabric of reality, and is not a construct. If the world-lines of two entities are said to be real, then time, as one of the dimensions of those world-lines must also be real. Yolton uses this unique status of time in Eddington's thought to prove that Eddington was a realist. See Yolton, 116-18

[54] NPW, 91

[55] NPW, 89

[56] This basic insight has been extensively developed within the Buddhist notion of *anitya*, where all things are seen to be impermanent, changing and momentary. For a good introduction to this notion see T. R. V. Murti, *The Central Philosophy of Buddhism* (London: Unwin Paperbacks, 1980).

[57] NPW, 276

[58] PPS, 184-186

[59] NPW, 280. The cycle of physics he refers to is the closed system of thought that it has constructed for itself, in which it need never concern itself with the outside world. The cycle starts at the interval, goes on to scales and measures, to matter, to stress, to potentials, and finally back to the interval. Each item is used in the definition of the next, but reality itself never really enters the picture. See NPW, 241-263, esp. 255

[60] NPW. 281

[61] NPW, 281. In PPS he spends some time discussing the "Laws" of nature, and how such scientific principles are mind-made. The implication for philosophy is that the "totality of mind-made laws does not impose determinism" on the physical world, rather, the real nature of the

world remains free of our subjective impositions. PPS, 180

[62] He introduces the label "spiritual" for the mental reality quite without warning. While this switch in labels would seem significant, Eddington uses them interchangably. See NPW, 281-82

[63] DPS, 199

[64] PPS, 184

[65] NPW, 288-89

[66] A. S. Eddington, *Science and Religion*, (Friends Home Service Committee, 1931) 13

[67] DPS, 221-22

[68] NPW, 288

[69] It would be interesting to explore the possibility of Eddington's reticence regarding ultimate reality and his Quakerism, especially in conjunction with the possibility that Kant's insistence that we can never know the "Ding an sich" is related to his involvement in Pietism. A. D. Ritchie has noted the possibility of some connection here too: "Kant's view of the definite limits of science knowledge and its separation from the extra-scientific realm was sympathetic to Eddington's outlook. Kant had been deeply influenced by the East Prussian Pietists, as Eddington had by the Quakers." *Reflections on the Philosophy of Sir Arthur Eddington.* (Cambridge: UP. 1948) 2-3

[70] ST&G, 200-201. He does not actually claim that the epistemological search will yield more truth about reality, but he certainly attempts to lead in that direction. It would perhaps be true to say that an inquiry into epistemology would reveal more about mind, and thus about the constructed universe, but certainly never anything about the underlying reality.

[71] NPW, 282

[72] NPW, 286

[73] NPW, 282

[74] NPW, 286

[75] I am here following the argument given by Johannes

Witt-Hansen, *Exposition and Critique of the Conceptions of Eddington Regarding the Philosophy of Physical Science.* (Copenhagen: G. E. C. Gads Vorlag, 1958) 51ff

[76] PPS, 150

[77] PPS, 151

[78] Note that this conclusion is highly disputable. Firstly, because what is described here is not really a *priori*, since considerable knowldege of human nature is pre-supposed. Secondly, the premise that knowledge of possible human thought processes can lead us to knowledge of the world of physics is disputable. Of particular interest is E. T. Whittaker's rebuttal as given in "Some Disputed Questions in the Philosophy of the Physical Sciences" (*Proceeding of the Royal Society of Edinborough, A41.* 1942) p 160-175, especially 169ff. While Whittaker's point--that many of the "self-evident" principles which Eddington assumes to be *a priori* are in fact the result of extensive experimentation--is valid, Eddington's point is too. I would suggest that Eddington wants to say that *physical knowledge*, that is, knowledge of what we call the universe, is structural knowledge; it is knowledge that is informed by *both* the unknown "reality" and the intellectual and physical make-up of human beings. Thus if humans had different faculties, that which we call the universe would have a different set of descriptors; and it then makes sense to say that the universe is "no more than a form of thought" even though it is based on some underlying reality, because our "description of the world" is what we are referring to. That reality itself is, however, independent of humans.

[79] PPS, 60

[80] Witt-Hansen, 52

[81] PPS, 27

[82] PPS, 57

[83] PPS, 3

[84] Witt-Hansen, 52

[85] PPS, 69

[86] PPS, 223

[87] NPW, 287-88

Chapter Three

[1] NPW, 283

[2] John W. Yolton, *The Philosophy of Science of A. S. Eddington*, (The Hague: Martinus Nijhoff Verlag, 1960) 109

[3] NPW, 268

[4] Sir A. S. Eddington, *Science and Religion*. (Friends Home Service Comittee, 1931) 4

[5] *Science and Religion*, 5

[6] *Science and Religion*, 5

[7] *Science and Religion*, 12f

[8] *Science and Religion*, 5

[9] *Science and Religion*, 5-6

[10] *Science and Religion*, 6

[11] *Science and Religion*, 10

[12] See the material quoted on pages 61-62, (note 7) above.

[13] *Science and Religion*, 12

[14] A. S. Eddington, "The Domain of Physical Science," in *Science, Religion and Reality*. ed by Joseph Needham (New York: George Braziller, Inc., 1955) 194. Henceforth DPS.

[15] DPS, 194

[16] DPS, 195

[17] DPS, 195

[18] DPS, 196

[19] DPS, 200. I assume he is referring to the school of philosophy based on the work of Ernst Mach (1838-1916).

[20] DPS, 200

[21] DPS, 200

[22] DPS, 200-201

[23] DPS, 201

[24] DPS, 202

[25] DPS, 202-203

[26] DPS, 203

[27] DPS, 203-204
[28] DPS, 204

[29] DPS, 204

[30] Among many others, E. F. Schumacher, in *A Guide for the Perplexed*, (London: Abacus, 1978) outlines the basics of the Perennial Philosophy, and indicates that to use the methods of physics, which are designed to analyze matter, on higher levels of being is a gross mistake in category. Thus phyical science can never tell us about anything other than about physical things. Knowledge of human nature, God, life, or any other higher level of being requires specialized methods appropriate to the subject matter. Eddington seems to have known this on an instinctive level. Lawrence Leshan and Henry Margenau in *Einstein's Space & Van Gogh's Sky* (New York: Collier Books, 1982) 98 discuss a different understanding of levels which is non-hierarchical, and involves using different realities for each level, where each reality has different observables and laws. Attempting to explain a "paranormal" phenomenon from within a reality in which it is impossible for such a phenomenon to occur is pointless, and a mistake in realms/realities.

[31] DPS, 204

[32] DPS, 216

[33] DPS, 216-217

[34] DPS, 218

[35] ST&G, 196

[36] ST&G, 197

[37] ST&G, 198. One of the fundamental characteristics of this common reality is that it is permanent. Eddington supposes that "the mind has by diligent search picked out the possible constructs which have this permanence in virtue of their mode of construction, and by giving these value and ignoring the rest has imposed a law of

conservation of the things of value." DPS, 217. Further, he notes that this may be a function of natural selection; minds which did not pick up on permanent objects may have had a hard time of functioning and surviving! DPS, 217-18

[38] ST&G, 198

[39] ST&G, 198

[40] ST&G, 200

Chapter Four

[1] St. John of the Cross as quoted by an unnamed Quaker at a Meeting at which Douglas V. Steere was in attendance, as found in Douglas V. Steere, ed., *Quaker Spirituality: Selected Writings* (New York: Paulist Press, 1984) 16

[2] A. Vibert Douglas, *The Life of Arthur Stanely Eddington.* (London: Thomas Nelson and Sons, Ltd., 1957) 128

[3] Quaker meetings are described in *Quaker Spriturality*, 26ff

[4] At least that was the case in the 19th century, *Quaker Spirituality*, 34

[5] Douglas, 131

[6] A. S. Eddington, *Science and Religion*, (Friends Home Service Committee, 1931) 6

[7] NPW, 283

[8] *Quaker Spirituality*, 34

[9] *Quaker Spirituality*, 267

[10] Science and Religion, 12

[11] PPS, 184

[12] *Quaker Spirituality*, 34

[13] cf. NPW, 327f

[14] Hoylands, as quoted in A. S. Eddington, *Science and the Unseen World*, (London: George Allen & Unwin, 1929) 28f

[15] Science and the Unseen World, 28f

[16] Rupert Brooke, in NPW, 317

[17] NPW, 317

[18] Science and the Unseen World, 28

[19] *Quaker Spirituality*, 254

[20] Science and Religion, 13

[21] NPW, 322-23

[22] *Quaker Spirituality*, 15

[23] Isaac Penington, in *Quaker Spirituality*, 150

[24] Science and the Unseen World, 30-31

[25] *Quaker Spirituality*, 145

[26] NPW, 321

[27] Steere, in *Quaker Spirituality*, 5

[28] A. S. Eddington, *New Pathways in Science*, (Cambridge: UP, 1935) 322

Conclusion

[1] There is, of course, a wide variety of interpretation of Kant's thought. I am basing my interpretation largely on C. F. von Weizsäcker's *The Unity of Nature* (trans. by Francis J. Zucker. New York: Farrar, Straus Giroux, 1980), especially chapters II.3 and IV.2 and IV.3. In the interpretation of Kant given by von Weizsäcker in chapter II.3 of *Unity*, Kant's programme leads to a situation in which we would be able to deduce "in principle. . . the existence and number. . . of the so called elementary particles. . . each and every line in the spectrum of iron, and all the laws of celestial mechanics." *Unity*, 155. The similarity to Eddington's programme is startling.

von Weizsäcker presents an alternate interpretation in chapters IV.2 and IV.3. Since he admits that he has not attempted to reconcile the alternate interpretations (*Unity*, 327) I think it is acceptable that this thesis does not attempt to do so either.

[2] PPS, 176

[3] Sir Edmund Whittaker, *Eddington's Principle in the Philosophy of Science.* (Cambridge: UP, 1951) 4. See also Sir Edmund Whittaker, *From Euclid to Eddington: A study of conceptions of the external world.* (New York: Dover Publ. Inc., 1958), especially pp 185-204.

BIBLIOGRAPHY

Armstrong, D. M. *Perception and the Physical World.* London: Routledge & Kegan Paul, 1961.

Bell, J. S. "Subject and Object." *The Physicist's Conception of Nature.* pp 687-690. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

Bohm, David. *Quantum Theory.* New York: Prentice Hall, 1951.

_____. *Causality and Chance in Modern Physics.* London: Routledge & Kegan Paul, 1957.

_____. *Wholeness and the Implicate Order.* London: Ark Paperbacks, 1980, 1983.

_____. *The Special Theory of Relativity.* New York, Amsterdam: W. A. Benjamin, 1965.

Braithwaite, R. B. "Professor Eddington's Gifford Lectures." *Mind* 38 (1929) 409-435.

_____. "Indeterminacy and Indeterminism." *Proceedings of the Aristotelian Society. Supplements* 10 (1931) 183-196.

_____. "Review of *The Philosophy of Physical Science* by Sir Arthur Eddington." *Mind* 49 (1940) 455-466.

_____. *An Empiricist's View of the Nature of Religious Belief.* The Ninth Arthur Stanley Eddington Memorial Lecture, 22 November 1955. Cambridge: University Press, 1955.

Bridgman, Percy William. *Reflections of a Physicist.* 2nd ed. New York: Philosophical Library, 1950, 1955.

Broad, C. D. "The Philosophical Aspect of the Theory of Relativity (Symposium)." *Mind* 29 (1920) 430-437.

_____. "Indeterminacy and Indeterminism." *Proceedings of the Aristotelian Society.* Supplements 10 (1931) 135-160.

Broad, C. D. "The Present Relations of Science and Religion." *Philosophy* 14 (1939) 131-154.

_____. "Sir Arthur Eddington's The Philosophy of Physical Science." *Philosophy* 15 (1940) 301-312.

Brown, Burniston. "Why do Archimedes and Eddington both get 10^{79} for the total number of particles in the Universe?" *Philosophy* 15 (1940) 269-284.

Brown, R. Hanbury. "The Nature of Science." *Zygon* 14 (Sept 1979) 201-215.

Brown, Sanborn C. "Contributions of Science to the Unitarian Universalist Tradition: A Physicist's View of Religious Belief." *Zygon* 14 (March 1979) 41-52.

Budenholzer, Frank E. "Science and Religion: Seeking a Common Horizon." *Zygon* 19 (Sept 1984) 351-368.

Bunge, Mario. *Method, Model and Matter*. Boston: D. Reidel, 1973.

_____. *Philosophy of Physics*. Boston: D. Reidel, 1973.

Campbell, Norman. "The Errors of Sir Arthur Eddington." *Philosophy* 6 (1931) 180-192.

Capek, Milic. *The Philosophical Impact of Contemporary Physics*. Princeton: D. van Norstrand Co., 1961.

Capra, Fritjof. *The Tao of Physics*. 2nd ed. Boulder: Shambala, 1983.

_____. *The Turning Point*. Toronto: Bantam New Age Books, 1983.

Chandrasekhar, S. *Eddington: The most distinguished astrophysicist of his time*. Cambridge: University Press, 1983.

Cooper, Leon N. "Wavefunction and the observer in quantum theory." *The Physicist's Conception of Nature*. pp 668-683. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

Cornman, James W. "Can Eddington's Two Tables be Identical?" *Australian Journal of Philosophy* 52 (May 1974) 22-38.

Coulson, C. *Science and the Idea of God.* The Eleventh Arthur Stanley Eddington Memorial Lecture, 21 April 1958. Cambridge: University Press, 1958.

Crowther, J. G. *British Scientists of the Twentieth Century.* London: Routledge & Kegan Paul, 1952.

d'Aquili, Eugene G. "The Sense of Reality in Science and Religion: A Neuroepistemological Perspective." *Zygon* 17 (Dec 1982) 361-385.

d'Espagnat, Bernard. "Quantum logic and non-seperability." *The Physicist's Conception of Nature.* pp 714-735. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

De Koninck, Charles. "Random Reflections on Science and Calculation." *Laval Theologique et Philosophique* 12 (1956) 84- 119.

Dingle, Herbert. *The Sources of Eddington's Philosophy.* Cambridge: University Press, 1954.

Dirac, P. A. M. "Development of the physicist's conception of nature." *The Physicist's Conception of Nature.* pp 1-14. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

Douglas, A. Vibert. *The Life of Arthur Stanley Eddington.* London: Thomas Nelson and Sons, 1957.

Drieschner, Michael. "Physik a priori?." *Moderne Naturphilosophie.* pp 41-61. Edited by Bernulf Kanitscheider. Verlag Dr. J. Königshausen + Dr. Thomas Neumann: Würzburg, 1983, 1984.

Books by Eddington:

Eddington, A. S. *Space, Time and Gravitation: An outline of the general relativity theory.* Cambridge: University Press, 1921

_____. *The Theory of Relativity and its Influence on Scientific Thought.* Romanes Lecture, 1922. Oxford: Clarendon Press, 1922.

_____. *The Mathematical Theory of Relativity.* Cambridge: University Press, 1923.

_____. *The Nature of the Physical World.* The Gifford Lectures, 1927. New York: Macmillan, 1929.

_____. *Science and the Unseen World.* London: George Allen & Unwin, 1929.

_____. *Science and Religion.* Friends Home Service Committee, 1931.

_____. *The Expanding Universe.* Cambridge: University Press, 1933.

_____. *New Pathways in Science.* Messenger Lectures, 1934. Cambridge: University Press, 1935.

_____. *The Philosophy of Physical Science.* Tarner Lectures, 1938. Ann Arbor: University of Michigan Press, 1958.

Articles by Eddington:

_____. "The Meaning of Matter and the Laws of Nature according to the Theory of Relativity." *Mind* 29 (1920) 145-158.

_____. "The Philosophical Aspect of the Theory of Relativity (Symposium)." *Mind* 29 (1920) 145-158.

_____. "Physics and Philosophy." *Philosophy* 8 (1933) 30- 43.

_____. "Cosmological Applications of the Theory of Quanta." *New Theories in Physics: conference in Warsaw, 1938.* Paris, 1939.

_____. "Group Structure in Physical Science." *Mind* 50 (1941) 268-279.

_____. "The Domain of Physical Science." *Science, Religion and Reality.* pp 191-222. Edited by Joseph Needham. New York: George Braziller, Inc., 1955.

Einstein, A. *The World As I See It.* Translated by Alan Harris. London: John Lane the Bodley Head, 1935.

_____. "Bemerkungen zu Bertrand Russells Erkenntnis-Theorie." *The Philosophy of Bertrand Russell.* 3rd ed. pp 278-291. Edited by Paul Arthur Schilpp. Library of Living Philosophers, 1944; Harper Torchbooks, 1963.

Feigl, Herbert. "Russell and Schlick." *Erkenntnis* 9 (1975) 11-34.

Finkelstein, David. "A process conception of nature." *The Physicist's Conception of Nature.* pp 709-713. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

Fowler, Dean R. "Einstein's Cosmic Religion." *Zygon* 14 (Sept 1979) 267-279.

Gomborow, Joel. "The Physical World and Reality." *Philosophy* 10 (1935) 453-466.

Green, Peter. "Time, Space and Reality." *Philosophy* 9 (1934) 461- 464.

Gregorios, Paulos Mar. *The Human Presence: An orthodox view of nature.* Madras, India: The Christian Literature Society, 1980.

Grünbaum, Adolf. "The Anisotropy of Time." *The Monist* 48 (1964) 219- 247.

_____. *Geometry and Chronometry in Philosophical Perspective.* Minneapolis: University of Minnesota Press, 1968.

_____. *Philosophical Problems of Space and Time.* 2nd ed. Edited by Robert S. Cohen and Marx W. Wartofsky. Dordrecht, Holland: D. Reidel, 1973.

Haag, R. "Subject, object and measurement." *The Physicist's Conception of Nature.* pp 691-696. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

Hardie, C. D. "The Relations between Science and Philosophy." *Mind* 49 (1940) 108-116.

Harman, P. M., ed. *Wranglers and Physicists: Studies on Cambridge physics in the nineteenth century.* Manchester: University Press, 1985.

Hefner, Philip. "Science and Religion: Athens and Jerusalem in Dialogue about Athen's Salvation." *Zygon* 14 (Sept 1979) 217-229.

Heisenberg, Werner. *Physics and Philosophy.* New York: Harper Torchbooks, 1962.

_____. "Development of concepts in the history of quantum theory." *The Physicist's Conception of Nature.* pp 264- 275. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

Hendry, John., ed. *Cambridge Physics in the Thirties.* Bristol: Adam Hilger, 1984.

Hentschel, Klaus. "Einstein, Neokantianismus und Theorienholismus." *Kant-Studien* 78 (1987) 459-470.

Hicks, G. Dawes. "Professor Eddington's Philosophy of Nature." *Proceedings of the Aristotelian Society* 29 (1929) 275-300.

Hoare, F. R. "Indeterminacy and Indeterminism." *Philosophy* 9 (1932) 393-403.

Honner, John. "Niels Bohr and the Mysticism of Nature." *Zygon* 17 (Sept 1982) 243-253.

Hooper, S. E. "Whitehead's Philosophy: "Theory of Perception"." *Mind* 49 (1940) 136-1582.

Hoskin, Michael., gen. ed. *The General History of Astronomy.* Cambridge: University Press, 1984. Vol. 4. *Astrophysics and twentieth-century astronomy to 1950: Part A.* Ed. by Owen Gingerich.

Inge, W. R. "Science, Philosophy and Religion." *Philosophy* 9 (1934) 146-156.

Jacks, L. P. *Sir Arthur Eddington: Man of Science and Mystic.* The Second Arthur Stanley Eddington Memorial Lecture, 1948. Cambridge: University Press, 1949.

Jauch, Josef M. "The problem of measurement in quantum mechanics." *The Physicist's Conception of Nature.* pp 684-686. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

Jeans, Sir James. "The Mathematical Aspect of the Universe." *Philosophy* 7 (1932) 3-14.

_____. *The Mysterious Universe.* Cambridge: University Press, 1948.

Joad, C. E. M. "Symposium: Realism and Modern Physics." *Proceedings of the Aristotelian Society.* Supplements 10 (1931) 126-145.

_____. *Philosophical Aspects of Modern Science.* London: George Allen & Unwin, 1932.

Jones, Richard H. "Experience and Conceptualization in Mystical Knowledge." *Zygon* 18 (June 1983) 139-165.

Kant, Imanuel. *Prolegomena to any future metaphysics that will be able to come forward as science.* The Paul Carus translation, extensively revised by James W. Ellington. Indianapolis: Hackett, 1977.

Kanitscheider, Bernulf. "Naturphilosphie und analytische Tradition." *Moderne Naturphilosophie.* pp 63-79. Edited by Bernulf Kanitscheider. Verlag Dr. J. Konigshausen + Dr. T. Neumann: Wurzburg, 1983, 1984.

Klemke. E. D., ed. *Introductory Readings in the Philosophy of Science.* New York: Prometheus Books, 1980.

Laird, J. "Symposium: Realism and Modern Physics." *Proceedings of the Arsitotelian Society.* Supplements 10 (1931) 112-125.

Lambert, Karel and Gordon G. Brittan, Jr. *An Introduction to the Philosophy of Science.* New Jersey: Prentice-Hall, 1970.

Leshan, Lawrence, and Henry Margenau. *Einstein's Space & Van Gogh's Sky.* New York: Collier Books, 1982.

Leslie, John. "The Value of Time." *Americal Philosophical Quarterly* 15 (1976) 109-121.

Lindemann, F. A. "The Philosophical Aspect of the Theory of Relativity (Symposium)." *Mind* 29 (1920) 437-445.

_____. "The Place of Mathematics in the Interpretation of the Universe." *Philosophy* 8 (1933) 14-29.

Losse, John. *A Historical Introduction to the Philosophy of Science.* 2nd ed. Oxford: University Press, 1980.

Ludwig, G. "Why a new approach found quantum theory?" *The Physicist's Conception of Nature.* pp 702-708. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

Marquis, Donald B. "In Defence of Sir Arthur Eddington." *Southwestern Journal of Philosophy* 7 (1976) 137-143.

Mascall, E. L. *Christian Theology and Natural Science: Some questions in their relations.* London: Longmans, Green and Co., 1957.

McConnell, James R. "Reflections on Physical Theories." *Philosophical Studies* (Ireland) 18 (1969) 7-13.

McNicholl, A. J. "Science and Philosophy." *The Thomist* 8 (1945) 68- 130.

Meyerson, Emile. *Boston Studies in the Philosophy of Science.* Vol. 83. *The Relativistic Deduction: Epistemological Implications of the Theory of Relativity.* Translated by David A. and Mary-Alice Sipfle. Dordrecht: D. Reidel, 1985.

Milne, E. A. "Some Points in the Philosophy of Physics: Time, Evolution and Creation." *Philosophy* 9 (1934) 19-50.

Mittelstaedt, Peter. *Philosophical Problems of Modern Physics.* Translated by Dr. W. Reimer. Boston: D. Reidel, 1963, 1976.

Morrison, Roy D. II. "Albert Einstein: The Methodological Unity Underlying Science and Religion." *Zygon* 14 (Sept 1979) 255-265.

Moser, Paul K., ed. *A Priori Knowledge.* Oxford: University Press, 1987.

Murdoch, Vilem. *Kantstudien: Ergänzungshefte.* Vol. 119. *Kants Theorie der physikalischen Gesetze.* Berlin: Walter de Gruyter, 1987.

Nagel, Ernst. "Russell's Philosophy of Science." *Philosophy of Science.* pp 55-68. Edited by Arthur Danto and Sidney Morgenbesser. Meridian Books, New York: World, 1960.

Neumann, Paul-Heinz. "Der Begriff der Analyse bei Eddington." *Philosophia Naturalis* 9 (1978) 533-541.

North, J. D. *The Measure of the Universe: A history of modern cosmology.* Oxford: Clarendon Press, 1965.

Novitz, David. "Primary and Secondary Qualities: A return to fundamentals." *Philosophical Papers* 4 (1975) 89-104.

Palmquist, Stephen. "Knowledge and Experience." *Kant-Studien* 78 (1987) 172-200.

Peters, Karl E. "Editorial." *Zygon* 14 (Sept 1979) 195-199.

Planck, Max. *Where is Science Going?.* Translated by and edited by James Murphy. London: George Allen & Unwin, 1933.

Polanyi, Michael. "Genius in Science." *Methodological and Historical Essays in the Natural and Social Science.* pp 57-71. Edited by Robert S. Cohen and Marx W. Wartofsky. Boston: D. Reidel, 1974.

Price, H. H. *Some Aspects of the Conflict Between Science and Religion.* The Seventh Arthur Stanley Eddington Memorial Lecture, 1953. Cambridge: University Press, 1953.

Prigogine, Ilya. "Measurement process and the macroscopic level of quantum mechanics." *The Physicist's Conception of Nature.* pp 697-701. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

_____. "Time, irreversibility, and structure." *The Physicist's Conception of Nature.* pp 561-593. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

Prigogine, Ilya and Isabelle Stengers. *Order Out of Chaos.* Toronto: Bantam Books, 1984.

Primas, Hans. "Verschränkte Systeme und Komplementarität." *Moderne Naturphilosophie.* pp 243-260. Edited by Bernulf Kanitscheider. Verlag Dr. J. Königshausen + Dr. T. Neumann: Würzburg, 1983, 1984.

Raschke, Carl. "From God to Infinity, or How Science Raided Religion's Patent on Mystery." *Zygon* 17 (Sept 1982) 227-241.

Reiser, Oliver L. "Physics, Probability and Multi-Valued Logic." *The Philosophical Review* 49 (1940) 662-672.

Riggan, George Arkell. "Quantum Physics and Freedom in a Whiteheadian Perspective." *Zygon* 17 (Sept 1982) 255-265.

Ritchie, A. D. *Reflections on the Philosophy of Sir Arthur Eddington.* The First Arthur Stanley Eddington Memorial Lecture, 4 November 1947. Cambridge: University Press, 1948.

Rosenthal-Schneider, Ilse. *Reality and Scientific Truth: Discussions with Einstein, von Laue, and Planck.* Detroit: Wayne State University Press, 1980.

Ross, W. D. "The Philosophical Aspect of the Theory of Relativity (Symposium)." *Mind* 29 (1920) 423-430.

Russell, Bertrand. "Review of The Expanding Universe, by Sir Arthur Eddington." *Philosophy* 8 (1933) 219-220.

_____. "Review of New Pathways in Science by Sir Arthur Eddington." *Philosophy* 10 (1935) 483-485.

_____. "The Relation of Sense-Data to Physics." *Philosophy of Science*. pp 33-54. Edited by Arthur Danto and Sidney Morgenbesser. New York: World Pub. Co., 1960.

Ryle, Gilbert. *Dilemmas*. The Tarner Lectures, 1953. Cambridge: University Press, 1954.

Sagan, Carl. *The Comic Connection*. New York: Anchor Books, 1973.

Schlegel, Richard. "Is Science the Only Way to Truth?." *Zygon* 17 (Dec 1982) 343-359.

Schlegel, Richard. "Quantum Physics and the Divine Postulate." *Zygon* 14 (June 1979) 163-185.

Schumacher, E. F. *A Guide for the Perplexed*. London: Abacus, 1978.

Seeger, Raymond J. "On Understanding Physical Phenomena." *Proceedings of the American Catholic Philosophical Association* (1964) 47-73.

Sellars, Roy Wood. "Critical Realism and Substance." *Mind* 38 (1929) 473-488.

_____. *The Philosophy of Physical Realism*. New York: Macmillan, 1932.

Sellars, W. *Science, Perception and Reality*. London: Routledge & Kegan Paul, 1963.

Shapere, Dudley. "Natural Science and the Future of Metaphysics." *Methodological and Historical Essays in the Natural and Social Sciences*. pp 161-171. Edited by Robert S. Cohen and Marx W. Wartofsky. Boston and Dordrecht, Holland: D. Reidel, 1974.

Smart, J. J. C. *Philosophy and Scientific Realism*. London: Routledge & Kegan Paul, 1963.

Stace, W. T. "Sir Arthur Eddington and the Physical World." *Philosophy* 9 (1934) 39-50.

Stebbing, L. Susan. "Symposium: Realism and Modern Physics." *Proceedings of the Aristotelian Society.* Supplements 10 (1931) 146-161.

_____. *Philosophy and the Physicists.* London: Methuen & Co. Ltd., 1937.

_____. "Furniture of the Earth." *Philosophy of Science.* pp 69-81. Edited by Arthur Danto and Sidney Morgenbesser. Meridian Books, New York: World, 1960.

Steere, Douglas V., ed. *Quaker Spirituality: Selected Writings.* The Classics of Western Spirituality. New York: Paulist Press, 1984.

Theobald, D. W. *An Introduction to the Philosophy of Science.* London: Methuen and Co., 1968.

Törnebohm, Håken. "Die Rolle der Naturphilosophie in der physikalischen Forschung." *Moderne Naturphilosophie.* pp 15-39. Edited by Bernulf Kanitscheider. Verlag Dr. J. Königshausen + Dr. T. Neumann: Würzburg, 1983, 1984.

Tyrell, G. N. M. "Physics and the Ontological Problem." *Philosophy* 7 (1932) 404-413.

Walsh, W. H. "Kant's Conception of Scientific Knowledge." *Mind* 49 (1940) 445-450.

Wavell, Bruce B. "Scientific and Religious Universes of Discourse." *Zygon* 17 (Dec 1982) 326-341.

Weizsäcker, C. F. v. *The World View of Physics.* Translated by Marjorie Grene. London: Routledge and Kegan Paul, 1952.

_____. "Classical and quantum descriptions." *The Physicist's Conception of Nature.* pp 635-667. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

_____. "Physics and Philosophy." *The Physicist's Conception of Nature.* pp 736-746. Edited by Jagdish Mehra. Dordrecht, Holland: D. Reidel, 1973.

_____. *The Unity of Nature.* Translated by Francis J. Zucker. New York: Farrar, Straus Giroux, 1980.

Whittaker, E. T. "Some Disputed Questions in the Philosophy of the Physical Sciences." *Proceedings of the Royal Society at Edinburgh, A41* (1942) 160-175.

_____. *Eddington's Principle in the Philosophy of Science.* The Fifth Arthur Stanley Eddington Memorial Lecture, 9 August 1951. Cambridge: University Press, 1951.

_____. *From Euclid to Eddington: A study of conceptions of the external world.* New York: Dover Pub. Inc., 1958.

Wilber, Ken, ed. *The Holographic Paradigm and Other Paradoxes.* Boulder & London: Shambala, 1982.

_____., ed. *Quantum Questions.* Boulder & London: Shambala, 1984.

Witt-Hansen, Johannes. *Exposition and Critique of the Conceptions of Eddington Concerning the Philosophy of Physical Science.* Copenhagen: G. E. C. Gads Forlag, 1958.

Wood, H. G. *Thought, Life and Time: As reflected in science and poetry.* The Tenth Arthur Stanley Eddington Memorial Lecture, 19 February 1957. Cambridge: University Press, 1957.

Wright, Larry. "Rival Explanations." *Mind* 82 (1973) 497-515.

Yolton, John W. *The Philosophy of Science of A. S. Eddington.* The Hague: Martinus Nijhoff, 1960.