THE DOCTRINE OF STRUCTURE AND ITS PHILOSOPHICAL IMPLICATIONS IN EDDINGTON'S PHILOSOPHY OF KNOWLEDGE

by

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CHAPTER I

INTRODUCTION

In these days of specialization in all fields of academic disciplines, it is given to few to have a wide range of interests, and to make correspondingly wide contributions of outstanding merit. One of these few was Sir Arthur Stanley Eddington (1882-1944), an astrophysicist, an eminent mathematician, and a philosopher. It was through his enduring investigations and daring venture in finding out the constitutions, motions, and distances of the heavenly bodies that his philosophy evolved. Being one of the most brilliant theoreticians of his day, and having witnessed the many significant discoveries in the physical sciences, especially in physics, he found himself leaving the sphere of original research in astronomy more and more, to concentrate on the mathematical analysis and philosophical import of the new discoveries introduced by relativity and quantum theory. Realizing the tremendous philosophical implications of these modern theories in physics, he did not hesitate to make revisions and changes within his Victorian world-view. There is no doubt that he combined to a unique degree an appreciation of the significance of the new developments with great powers of mathematical analysis and keen physical intuition.

With the new developments in the exact sciences

and the transition from classical to modern physics, Eddington was faced with problems not only having to deal with the scientific community, but also with emerging issues within philosophical circles. The new discoveries of the relativity and quantum theory, especially, introduced into the philosophical community and the scientific world problems which bothered both the scientist and the philosopher. In particular, they bothered those who were engaged in the process of constructing a kind of philosophical system that tried to incorporate and accommodate the implications of modern physics. In this regard, Eddington keenly discussed with his contemporaries the apparent dualism between reality and mind that mechanics brought about and the apparent irreconcilability between the world of everyday experience and the world of physics. Specifically, Eddington sought an answer to the question: What is reality in the eyes of science and within these new discoveries? What does the scientist mean when he refers to the real world?

Stated in general philosophical terms, the question which occupied the mind of Sir Arthur Stanley Eddington was the question of the ontological status of the world which physics was exploring and the consequent epistemological and metaphysical assumptions and implications of the new physics. This was for Eddington the pre-eminent consideration among the many problems with which physical science bristled.

Throughout the whole trend of the history of physical science, there was a growing inconsistency between the world of physics and the world of common sense. [1] Eddington saw clearly this problem of reconciling these two worlds. For him, the solution lies in a construction of a viable epistemology, a 'scientific epistemology' within the context and demands of the world-view that the new discoveries brought about. He was convinced that only through a thorough consideration of epistemology could science advance further. He saw, in fact, that it was through the re-entry of epistemology, which prior physicists had thrown out as ancient history, that the whole revolution of classical physics, which gave birth to the relativity theory, had occured. "The re-entry into this neglected field (Epistemology) was the beginning of the modern revolutions of physics, the first result being the theory of relativity." [2]

Eddington maintains that a physicist is by origin a philosopher who has specialized in one direction. For when a physicist asks himself what it is that is really observed, and what the relation is of the observed with what

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1. Tyrell, G.N.M., "Physics and the Ontological Problem", in Philosophy, Vol. 7, No. 28, October 1932, p. 411.

2. Eddington, Stanley, Arthur, The Philosophy of Physical Science, Michigan, The University of Michigan Press, (Ann Arbor Paperback Series), 1958, (first published in 1939 by Cambridge University Press), p. 52. "Epistemology" was inserted by me. All references and quotes from henceforth will be made from this edition.

is given by common sense prior to scientific investigation, he has moved into the sphere of philosophy. On this point, Eddington says:

> Another appeal should be made to our rich relation epistemology who has rescued us on former occasions; another step forward should be taken in answering the fundamental question, what do we really observe? [3]

In short, when a scientist asks himself about the origins of the objects of observation and entities of experimentation, he virtually becomes a philosopher.

METAPHYSICS, EPISTEMOLOGY AND SCIENCE

Eddington saw clearly the importance of epistemology within the domain of the new physics. He viewed the assumptions of modern physics as philosophical in character. He was concerned with the epistemological aspects of the new world-view brought about by the new physics. Specifically, he was concerned with the revolution introduced by the new physics into the relation between the scientist as experimenter and knower, on the one hand, and the subject matter known, on the other. Prior to the birth of the new physics, nothing had happened in modern science that was of comparable significance for an appreciation of the role of epistemology in science. "From the time of Newton until recently, the epistemology of science was stationary; for

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3. Ibid., p. 53.

two hundred years the extension and order of our knowledge of the physical universe continued without modifying it".[4] Eddington wanted to awaken the scientific community on the importance of epistemology in the new physics, and to restore it in updated form to its proper place within physical science.

Most scientists today have accepted the ontological and epistemological presuppositions of modern science without question. As contemporary physics becomes more and more abstract in the formulation of conceptual schemes in the ordering of our knowledge of the physical universe, the harder it is for physics to do away with philosophy. Perhaps this is the reason why today, we see in both the physical sciences and the humanities different disciplines emerging, such as philosophy of physics, philosophy of biology, philosophy of mathematics, philosophy of sociology, etc. What Eddington tried to do is now regarded as indespensible to any sound scientific analysis of modern theories and to the systematization of the different parts of scientific thought. This is evident in the preface F.S.C. Northrop wrote for Werner Heisenberg's book, Physics and Philosophy. He says:

> Unquestionably, one other thing is clear. An analysis of specific experimentally verified theories of modern physics with respect to what they say about the object of human knowledge and its relation to the

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4. Ibid., p. 52.

> human knower exhibits a very rich and complex ontological and epistemological philosophy which is an essential part of the scientific theory and method itself. Hence, physics is neither epistemologically nor ontologically neutral. Deny any one of the epistemological assumptions of the physicist's theory and there is no scientific method for testing whether what the theory says about the physical object is true in the sense of being empirically confirmed. Deny any one of the ontological assumptions and there is not enough content in the axiomatically constructed mathematical postulates of the physicist's theory to permit the deduction of the experimental facts which is introduced to predict, coordinate consistently and explain. 5

Again, following the same pattern of thought on the relevancy of epistemology within science, Marx Wartoffsky says:

> The specific relevance of epistemology to philosophy of science concerns the instrumentalities for the acquisition and validation of scientific knowledge, the special aspects of the scientist's ways of coming to know. 6

In the systematic critical and speculative thought of science, metaphysics serves as the general conceptual framework within which scientific hypotheses and theories come to be formulated. It serves as a source of ideas and as a guide to the systematization of the different parts of

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5. Northrop, F.S.C., "Introduction", Werner Heisenberg, Physics and Philosophy, New York, Harper and Row, Publishers, (Harper Torchbooks, The Science Library edition), 1962, p. 25.

6. Wartoffsky, Marx, Conceptual Foundations of Scientific Thought, New York, The Macmillan Co., 1968, p. 13.

scientific thought. Even though the kind of things provided by metaphysics to science are truths which cannot be tested by experiment, they are, nonetheless, underlying, regulative, or heuristic ideas in science. They form the basic world-view of the scientist, the deep structure of his way of thinking, and constitute his belief about the nature of things. [7]

What we have been trying to say is that metaphysics and epistemology have finally found their place in the exact sciences. The scientists have finally come to recognize their importance, their place, and role in the construction of conceptual schemes, theories, and hypotheses used by physical science in its knowledge of the physical universe. This can in some measure be attributed to the insistence of Eddington on the necessity of an epistemological outlook in the development of modern theories concerning, for example, matter and radiation.

Eddington's strong emphasis on the role of epistemology within physical science, especially physics, was brought about by his study of the relativity theory and quantum mechanics. These two discoveries forced him to investigate in depth their implications for our knowledge of reality as revealed by physics. He was concerned about the implications of these theories of modern physics for the observer with respect to what he really observes and with respect to

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7. Ibid., p. 11.

what he knows about the really observed. Herbert Dingle in writing the 8th Arthur Stanley Eddington memorial lecture in 1954 wrote:

> Before the coming of relativity, his Victorian external world was something which sense observation revealed to him, and, like others, he believed that scientific discovery was making its character known. But relativity changed all that. [8]

What precisely the change was that the relativity theory brought about in Eddington's philosophy will be the main topic considered in chapter II which is devoted to the background of Eddington's philosophy.

PROBLEM

One of the most obvious questions that arises from modern physics is: Can the knowledge resulting from the scientist's techniques and methods in formulating his physical theories pass beyond what is merely phenomena or appearances to the ontological and intelligible reality of nature? This question is consequent upon the very nature of the scientist who is concerned with observing changes and characteristic stabilities. [9] To put it in another way, there seems to be a confusion within the scientist's mind about the

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8. Dingle, Herbert, The Sources of Eddington's Philosophy, 8th Sir Arthur Stanley Eddington memorial lecture, Cambridge University Press, 1954, p. 34.

9. Ashley, Benedict, "Does Natural Science Attain Nature or Only Phenomena," in St. John University Studies, edited by Vincent Smith, Philosophical series 2, p. 66.

perception of a thing as "out there" revealed to the senses and what is observed as subject-matter of physical analysis. The physicist adopts the perceptual standpoint that the world of ordinary experience exists independently of the perceiver and exists just as it is experienced. His objects are taken to be in reality as they appear to be in seeing and handling. Steel and brass are as they feel, namely, hard and heavy. When, however, he is theorizing about things, he drops this standpoint and assumes that his theoretical entities alone are real; that hardness, rigidity, heaviness and transparence are mere appearances and remote effects produced by theoretical entities in virtue of their own quite different properties. When he thinks about the perceptual process of other people, he adopts still another standpoint, a mixture of standpoints. What other people experience is a copy of the real properties of things, which copy is something inside their minds. The apparent irresolubility of this problem, resulted in a bifurcation of the nature of reality, a "familiar world" of tables, stones, sticks, smell, taste, and sound, and a "physical world" which consists of electrons, protons, mesons and positrons which have no color smell nor taste. [10] How Eddington will confront this phenomenon of the bifurcation of nature in the face of the question,

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10. Eddington, Stanley,Arthur, The Nature of the Physical World, Cambridge University Press, 1928, p. xvi.

What do we really know and how do we know it? will constitute the analysis of his "doctrine of structure", the main subject of our research.

At the heart of this bifurcation of nature, we can immediately detect the old problem of dualism. [11] The abstract character of physics makes this possible. For the physicist, science must abstract completely from the familiar and be grounded upon an immediate intuition of sense-data within our own subjective consciousness. Here a comparison between Eddington and a Cartesian viewpoint is helpful. The Cartesian object of science is presented as ideas of the mind. Their correlation with external reality is seen as being assured only by appeals to the veracity of God as author of nature and to the principle of causality. For Eddington, the objects of science are likewise sense-data present in the mind. But these sense-data, - the "first and most direct thing in our experience,"[12] are correlated with the "external reality" through the principle of structure. Eddington's starting-point, however, remains Cartesian, insofar as he maintains that "the only subject presented to me for study is the content of my consciousness." [13]

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11. Dualism here means a metaphysical classification, a schema for dividing everything without exception into two sorts of things that have nothing in common, and which therefore, exclude one another in their essential nature.

12. Eddington, Arthur Stanley, New Pathways in Science, Cambridge University Press, 1935, p. 281.

13. Ibid., p. 283.

Given this starting-point, Eddington tries to resolve the metaphysical and epistemological problem of dualism by means of his doctrine of structure.

As an empiricist, Eddington rejected the traditional notion of a universal, and reduced the activity of the intellect to the ordering and correlating of phenomena made known by the senses and as present in consciousness. The structural view of the universe conceived by Eddington is one that is subjectively constructed within consciousness. At this stage, it is sufficient to say that Eddington's doctrine of structure becomes a principle in the order of knowledge as well as a metaphysics of method whereby we obtain knowledge of the external world without knowing what this external world really is. It becomes a necessary doctrine for the validation and acquisition of physical knowledge. How Eddington's doctrine of structure assumes this significance becomes the subject-matter of chapter II.

Eddington's explicitation of his epistemological tenets, contains certain ambiguities, and uncertainties, which are mainly due to his inconsistent usage of terms. This also makes his works somewhat difficult to understand. Saying this, Herbert Dingle noted in fact that Eddington "left to philosophy a science of bewilderment and incredulity, to physics an enigma to solve, and to the student of human mentality a fascinating field for reflection".[14] All

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14. Dingle, The Sources of Eddington's Philosophy, p. 1.

of these, according to Dingle was a result of Eddington's not knowing what he was doing: "...he had no idea - or, more correctly, a quite false idea - of what his work really implied." [15]

Arthur Ritchie likewise noted the ambiguities of Eddington's thought as follows:

> Sometimes he seems to say that the whole visible and tangible world consists solely of 'ideas in the mind', at others that theoretical knowledge is the self-contained autonomous system developing itself according to its own logical nature. 16

It is not unusual for Eddington to come up with statements such as "an electron is something unknown... doing we don't know what." [17] The word 'electron' in Eddington's system is used indiscriminately for the physically defined entity and for its unknown counterpart. Despite these ambiguities and uncertainties, his position and the contribution he has made to human knowledge become clear in his works.

Accordingly, the problem that we wish to investigate can be summarized as follows: In efforts to explain man's knowledge of reality, philosophers and scientists have found themselves consistently confronted with the problem of the

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15. Ibid., p. 2.

16. Ritchie, Arthur, Reflections on the Philosophy of Sir Arthur Stanley Eddington, first Arthur Stanley Eddington memorial lecture, Cambridge University Press, 1948, p. 2.

17. Eddington, The Nature of the Physical World, pp. 224 plus 294.

apparent dualism of reality and mind. This dualism has not only influenced and conditioned man's religious and moral attitudes, but more immediately his reflective thought in both science and philosophy. [18] Eddington was faced with this very dualism in his analysis of the epistemological implications of modern physical theories. Although modern physics seems to set out from realistic preconceptions and premises, it seems to reduce the so-called physical universe to a bare 'X' of which we can say, at most, that there must be in it some difference corresponding to every difference in our perceptual content. Eddington advances a solution to the problem in his doctrine of structure - the key doctrine in the explicitation of his theory of knowledge. How does his doctrine of structure resolve for him the epistemological dualism of reality and mind, and the consequent metaphysical dualism of the thing in itself and the thing as known? The problem entails an investigation of the function that Eddington assigns to structure in the process of knowledge, which is a result of his doctrine of selective subjectivism. Our task is to present a philosophical analysis of Eddington's doctrine from an epistemological standpoint. This will entail an exposition of the content of structure and the essential role that it plays in his whole theory of physical knowledge.

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18. MacMurray, John, "The dualism of Mind and Matter," in Philosophy, vol. 10, no. 39, July 1935, p. 264.

There are previous works done on Eddington's philosophical system, but they do not bear at length on his doctrine of structure. We shall approach his thought through this doctrine from an epistemological standpoint and, at the same time, bring to the fore certain metaphysical implications.

Toward this end, we shall commence in Chapter II with an exposition of the historical background of Eddington's thought and a synthesis of the factors that shaped it, with emphasis on the role of relativity and quantum theory.

Chapter III will be an analysis of the doctrine of structure, bringing out its essential elements after the manner of Eddington. In this chapter, we shall also show how and why this doctrine is for Eddington the key to the problem of dualism.

Chapter IV will be an attempt to give a constructive evaluation and critical assessment of the doctrine. We shall do this from the viewpoint of philosophy, specifically from the viewpoint of moderate realism.

CHAPTER II

BACKGROUND OF EDDINGTON'S PHILOSOPHY

A. GENERAL INTRODUCTION

Eddington's philosophy is not merely an inquiry into the metaphysical and epistemological implications of modern physical theories nor an inquiry into the nature of the physical universe and our knowledge of it. It is, in addition, a kind of world-view, a conception of the world whose aim is to do justice to all fields of knowledge and experience. As mentioned previously, Eddington's intellectual life developed and matured in the midst of the new and significant discoveries in the scientific world. This network of important discoveries in the physical sciences influenced his thinking generally, and more especially his whole philosophy. Contemporary achievements in science were so much a part of him, that his philosophy inevitably bears the imprint of the scientific methodology that made them possible. It was in this sense that he could claim his epistemology to be 'scientific'. He intended his epistemology to be the core of a general philosophical outlook acceptable to scientists. "With this 'philosophy of physical science' as a neucleus", he writes, "I endeavour...to develop the outline of a general philosophical outlook which a scientist

can accept without inconsistency." [19] Despite the common base of this philosophy in science, he considers it to be his own, since the ultimate selection and synthesis must be a personal one. [20] We shall now try to unravel the influences of different scientific and philosophical systems on the selection and synthesis involved in the construction of his philosophy.

Accordingly, as a prologue to the examination of Eddington's specific 'doctrine of structure' and his system of epistemology, it is necessary to review briefly some aspects of his scientific and philosophical background. We shall attempt to expose the influences of the new discoveries in the physical sciences upon his whole epistemological system, especially as related to his 'doctrine of structure'. Since Eddington's philosophical insights were molded by the discoveries of physical science and the concurrent philosophical systems of this time, our review will include: First, the influence of scientific [21] elements, namely the theory of relativity and the quantum theory; and secondly, the

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19. Eddington, The Philosophy of Physical Science, p. ix.

20. Ibid., p. viii. Cf. McNicholl, Ambrose, "The Contemporary Challenge to the Traditional Ideal of Science," in The Thomist, Vol. 24, Nos. 2, 3 and 4, April, July, and October 1961, p. 592. "Philosophy, to be worthy of the name, cannot be the abstract and purely academic speculation of the university professor, but a personal thinking that is also a commitment."

21. "Scientific" here means for us the proper method of physical sciences, physics especially. It means a methodology in terms of observations, experimentations, and measurements.

philosophical influences, namely, the Kantian a priori, the causal theory of perception, and operationalism.

B. SCIENTIFIC INFLUENCE

1. RELATIVITY THEORY

The two new discoveries made by modern physics with which we are concerned are the theory of relativity and quantum theory. They played an important role and had lasting effects on the formation of Eddington's philosophical system. It is only in relation to this philosophical context that we shall consider these theories. They are important in the construction of Eddington's conception of the universe. R.B. Braithewaite in his critical review of Eddington's book, The Philosophy of Physical Science noted that "...Eddington's philosophy has behind it important researches in physics..." [22] In a similar vein, Johanness Witt-Hansen observed that when Eddington heard about Einstein's general theory of relativity during the first world war, "he immediately realized its significance" and "became one of its foremost interpreters and gave several comprehensive expositions of it." [23] Eddington wasted no time in probing the philosophical implications and consequences of these two theories. He mastered

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22. Braithewaite, R.B., "Critical Notices", a review of Eddington's book, The Philosophy of Physical Science, in Mind, Vol. 49, No. 196, October 1940, p. 455.

23. Witt-Hansen, Johanness, Exposition and Critique of the Conceptions of Eddington Concerning the Philosophy of Physical Science, Copenhagen, G.E.C. Gads, 1958, p. 24.

the mathematical methods used in the development and application of these theories and worked out the consequent philosophical implications. Accordingly, Eddington's world-view must be contemplated and surveyed from within his scientific world rather than from without. [24]

Before the birth of modern physics, the external world was considered to be simply the world revealed by sense observation. This was particularly the view of the physicists in the Renaissance, and in the Victorian era. Classical mechanics, allied with Newtonian physics, pictured the universe in terms of mass, energy, and magnetic force. It was a universe of entities to which we attach probabilities. It was couched in terms of mechanical ideas or a mechanical conception of nature which fits the events of everyday life. For example, it regarded space and time as absolute receptacles of perceived objects and held the fixity of absolute space as a frame of reference. It did not fully separate ontological questions from the operative task of physics. But when science extended the scope of its operations, viewing the farthest depths of space and even the innermost recesses of the atom, the mechanical concept failed and apparent contradictions in the order of phenomena of nature began to manifest themselves in science. Physicists soon discovered

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24. Ibid., p. 25.

that Newtonian mechanics cannot function at the quantal level and cannot adequately explain the problem raised by modern theories of motion and light propagation in relation to the observer.

It is true, however, that Newtonian mechanics was acknowledged to have a kind of principle of relativity, and to fulfill, to some extent, the demands of the new relativity theory. Heisenberg, in fact, fully recognized this aspect within Newtonian mechanics, when he said:

> In Newton's mechanics a certain principle of 'relativity' is fulfilled that can be described in the following terms: If in a certain system of reference the mechanical motion of bodies fulfills the law of Newtonian mechanics, then this is also true for any other frame of reference which is in uniform non-rotating motion with respect to the first system. Or, in other words, a uniform translational motion of system does not produce any mechanical effects at all and can therefore not be observed by such effects. 25

But Newtonian mechanics did not adequately explain the modern theories emerging from the experiments on the velocity of light in terms of the aether theory. Physicists arrived at the conclusion that Newtonian physics did not hold in modern optics or electrodynamics. At the level of quanta, a more feasible explanation was needed to account for the relativity

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25. Heisenberg, Werner, Physics and Philosophy, New York, Harper and Row, Publishers, Harper Torchbooks, The Library Science, 1962, copyright by Werner Heisenberg, 1958, pp. 112-113.

and probability factors in the behaviour of electrons and protons. This was found in the development of so-called 'wave mechanics'. It pictures the universe in terms of probability; its substance is comprised of probabilities expressed in the form of waves. The universe is a universe of probabilities to which we attach entities such as electrons, protons and photons. These entities are units of a similar kind, with their variety lying in their probability distribution. [26]

How did relativity theory affect the classical world-view of physics and traditional philosophy? How did it affect Eddington's conception of the universe? According to Eddington, himself, relativity theory reversed the definition of mass in terms of observable inertial properties to mass defined in terms of physical quantities, "regarded as defined by a series of measuring and calculations of which they are the result." [27] The world and bodies in the pre-relativity days were framed upon a fixed absolute space and motion. Within this frame, volume, mass, and measurements were regarded as determinations of the magnitudes of properties possessed by bodies. Relativity theory, however, changed and reversed all this. Herbert Dingle, in the work previously cited, provided a clear exposition of the change that relativity theory brought about in the following:

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26. Eddington, New Pathways in Science, pp. 128-129.

27. Eddington, The Philosophy of Physical Science, p. 71.

> All measures were now dependent on the motion of the observer, and the motion of the observer was not an objective thing, but something that could be assigned quite arbitrarily. Consequently, all measures become arbitrary, and the only things about them that could be called objective were certain mathematical relations. 28

Accordingly, before the theory of relativity, events could be ordered in time independent of their location. [29] But relativity theory provided a definition of mass in terms of inertial observable properties which permitted the experimenter to test statements concerning mass in terms of observations. [30] In layman's terms, it provided the experimenter with an indication of how to distinguish a quantity of matter as either potatoes or stones. C.D. Broad summarizes the fundamental innovation of this theory as follows:

> The fundamental innovation of the relativity theory was to define distance and time lapse in terms of operations and calculations which have to be performed in order to measure them. [31]

Likewise, the changes and reversals in science brought about by the relativity theory affected greatly the philosophies of the day, specifically cosmological world-view and epistemology. Relativity theory gave us an answer to the question: What do we really observe and what do we know about what we observe? We observe relations, Eddington

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28. Dingle, The Sources of Eddington's Philosophy, p. 34.

29. Heisenberg, Physics and Philosophy, pp. 126-127.

30. Eddington, The Philosophy of Physical Science, p. 89.

31. Broad, C.D., "Sir Arthur Eddington's The Philosophy of Physical Science", in Philosophy, Vol. 15, No. 59, 1948, p. 304.

says, [32] and we know the structure effected by these relations.

In keeping with this answer, Eddington exchanged his Victorian external world for a world of relations and relata, for systems of interconnections and networks of relational entities. Relativity theory provided Eddington with a model whereby he was able to construct mentally a world from relations that formed the essential elements of his physical universe. With the mind's active capacity in building a world, "at least one can build 'models' of the universe, cosmological pictures, the consequences of which can be compared with the empirical facts." [33] By implication, this theory transferred space, time, and motion from the physical to the mental world, and by doing so, "excluded the supposition that the physical world can be interpreted by analogy with visual sensa and their relation in the visual field." [34]

The relativity theory implicitly assigned a paramount role to the active character of the intellect and the sensory faculties in obtaining observational knowledge. What we know is conditioned subjectively, that is, it depends on

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32. Eddington, The Philosophy of Physical Science, p. 89.

33. Heisenberg, Physics and Philosophy, p. 125.

34. Lovejoy, Arthur, The Revolt Against Dualism; An Inquiry Concerning the Existence of Ideas, second edition, The Paul Carus lectures, series 2, La Salle, The Open Court Publishing Co., 1960, p. 346.

what Eddington sees as the constructional character of the mind. Everything is conditioned by the mind's very characteristic as active in constructing, relating and selecting; the mind imposes characteristics upon objects presented in a structural pattern. Everything now is dependent upon the standpoint of the observer at rest or in motion. When the theory of relativity brought this insight to the fore, it paved the way for seeing the mind as constructing a universe consisting of relations and entities which are expressible in terms of symbols, or a world reducible to an aggregate of point-events.

In terms of epistemology, the only objectivity left in knowledge was the objectivity of mathematical relations, and these relations revealed only the structure of the external world, and nothing at all about its nature. Relativity theory gave us a physical world whose essential elements were purely structures or a network of interrelated symbols. It did not reveal to us the real external world as revealed by the senses. Instead, it led us to a symbolic world which the mind constructs and builds from the symbols into a pattern or structure.

In brief, the philosophical implications for Eddington of the theory of relativity were as follows: First, it brought to the fore for him not only the subjectivity of human knowing in physical science, but the subjectivity of all human knowledge. It stressed a wholly active role for

the mind, with the result that the very concept of reality is conditioned by subjectivity. Secondly, since this subjectivity is selective in obtaining knowledge, it is only the structural element that the mind attains in the process of knowing. Consequently, it is the structure of reality presented to the mind in terms of symbols that we know. Structure becomes a kind of organizing principle within a subjective philosophy. Thirdly, it follows that the classical conception of matter as a principle of physical substance gives way to matter conceived as a property of a relational structure constructed selectively by the human mind. This paved the way for the mathematization of knowledge masquerading under the cloak of 'structuralism'. Accordingly, for Eddington, it is only through structure that the mind can know reality, thereby breaking down any seeming dualism between reality as perceived by common sense and reality as known by physical science.

2. QUANTUM THEORY

Eddington equally sensed the philosophical implications of the quantum theory despite the fact that during this time it was still obscure. Writing of the theory, he says that "although still rather obscure, it contains certain coherent lines of thought which have philosophical implications not less important than those of relativity theory." [35]

35. Eddington, The Philosophy of Physical Science, p. 28.

Toward a description of the physical universe, he was puzzled as to how he could fuse the relativity and quantum theory. In an effort to achieve this goal, he wrote a whole treatise [36] on the subject. The result of this effort was his invention of the 'E-algebra', which is explained in summary and modified form in his last book, Fundamental Theory. In the early stages, however, of the development of the quantum theory, Eddington did not appear to be too interested in the theory. The reason seems to be that it did not seem philosophically significant. In fact, the theory did not evoke any philosophical interest from the time of its initiation in 1901 by Max Planck's paper till 1925 with Werner Heisenberg [37] when he took the idea and formulated his well-known principle of uncertainty. It was only then that the theory, according to Eddington, acquired philosophical relevance, that is, when it assumed the name "wave mechanics", and "ceased to be entirely a collection of empirical magics." [38]

Like the relativity theory, the quantum theory provided the observer with an object to observe. The object takes the form of probabilities, and the observer attaches entities such as electrons and protons to these

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36. Eddington, Stanley, Arthur, The Combination of Relativity Theory and Quantum Theory, Dublin, The Dublin Institute for Advanced Studies, 1943.

37. Eddington, The Philosophy of Physical Science, p. 28.

38. Ibid., p. 28.

probabilities. [39] Aside from interpreting the universe as a world where only probabilities exist, the theory provided us with entities of minute atomic substructure, namely, molecules, atoms, electrons and protons, which do not at all appear in the "familiar story-world", but are, nevertheless, 'real entities.' [40] The minuteness especially of subatomic entities accounts for probability; for example, we can never pinpoint exactly the position of an electron, nor can we determine its velocity with any degree of precision. This is largely due to the unobservable-character of these high energy-quanta.

Eddington's inquiry into quantum mechanics was inseparably connected with the development of his epistemological ideas. He concluded from this inquiry that the laws of physics afford only probability connections for subsequent observations, and accordingly that they are subjective and predictable a priori. Eddington's epistemology assimilated within it the very elements of observation, namely, the instruments or apparatus that the observer uses, as well as the operation and calculation of measurement itself. An epistemology bearing upon these elements is directed towards an understanding of science, especially physics in terms of

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39. Eddington, New Pathways in Science, p. 128.

40. Ibid., p. 20.

its operational character. The one aspect common to both quantum theory and relativity theory is the rejection of concepts with no primitive observational base. [41] Observation, then, becomes a 'court of appeal' in Eddington's scientific epistemology: it becomes an integral part of philosophy accommodating the epistemological demands of modern physics. [42] Accordingly, we can conclude that, for Eddington, knowledge is purely a physical knowledge, that is, a knowledge obtained by observation. Observation becomes a category of knowledge in our knowledge of the universe.

Owing to this observational character of knowledge in Eddington's epistemology, it is evident that for him, whatever is not experimentally observable does not exist. We construe from this that a thing which does exist, or a process which goes on, during a certain time, even though unobserved, ceases to exist or go on at times during which physical conditions arise which would prevent it from being theoretically observable with a high degree of precision. [43] This subjectivism is augmented insofar as the demand of physical science to be verified by observation imposes a

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41. Wigner, Eugene, "Epistemology of Quantum Mechanics: Its Appraisal and Demands", in The Anatomy of Knowledge, Papers presented to the study group on Foundation of Cultural Unity, edited by Marjorie Grene, London, Routledge and Keagan Paul, 1969, p. 37.

42. Eddington, The Philosophy of Physical Science, p. 18.

43. Lovejoy, op. cit., p. 356.

selective test upon knowledge which is purely subjective. In this regard, Eddington says:

> If we take observation as the basis of physical science, and insist that its assertions must be verified by observation, we impose a selective test on knowledge which is admitted as physical. This selection is subjective, because it depends on the sensory and intellectual equipment which is our means of acquiring observational knowledge. 44

Similarly, Eddington saw the quantum theory as preempting causality of much of its realistic significance. The recurrencies and regularities of events within the probability wave led him to assert that the principle of causality is best expressed simply in terms of regularities and recurrencies. Causality is thereby reduced to the regularity of temporal sequence. Beyond this, causality becomes almost wholly subjective and useless to science. In this vein, he writes:

> The law of causality does not exist in science today - in that body of systematic knowledge and hypothesis which has been experimentally confirmed. It exists only in the anticipations of certain scientists - anticipations which naturally are colored by philosophical predilections. 45

Likewise, Eddington firmly believed that the question of indeterminacy and determinism was discarded by the quantum theory.

It is a consequence of the advent of the

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44. Eddington, The Philosophy of Physical Science, p. 17.

45. Eddington, New Pathways in Science, pp. 300-301.

> quantum theory that physics is no longer pledged to a scheme of deterministic law. Determinism has dropped out altogether in the latest formulations of theoretical physics and it is at least open to doubt whether it will ever be brought back. 46

Furthermore, he recognized that quantum mechanics had disembodied the notion of matter itself. Eddington agreed to the view of quantum theory that matter as perceivable through our senses is ultimately nothing else but an aggregation of elementary particles and of the processes that exist between them. Matter is merely a wave of probability, a collection of charges, in a system of spatio-temporal events whose qualities are exclusively mathematical. [47]

In brief, as a consequence of the quantum theory, Eddington denied the reality of causality, [48] determinism and even matter itself in the external world.

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46. Eddington, Stanley,Arthur, "Reality, Causation, Science, and Mysticism", in Man and The Universe - The Philosophers of Science, edited by Saxe Commins and Robert Lincott, New York, Washington Square Press, Inc., 1945, pp. 429-430. For a whole exposition of the question of determinism, we refer you to Eddington's article, "Indeterminacy and Indeterminism", in Proceedings of the Aristotelian Society, Supplementary Volume 10, 1954, pp. 160-182. And from the Thomist's point of view, we refer you to Yves Simon's article, "Maritain's Philosophy of the Sciences", in St. John University Studies, edited by Vincent Smith, Philosophical Series 2, pp. 36-37.

47. Joad, C.E.M., "Plato's Theory of Forms and Modern Physics", in Philosophy, Vol. 8, No. 30, April 1933, p. 145.

48. Eddington, The Nature of the Physical World, p. 309.

3. THEORY OF GROUP-STRUCTURE

Eddington realized that the kind of knowledge afforded by observation must be communicable. To make this possible, all the results of our observations, measurements and operations couched in their structural form must correspond to the conceptual interpretations of nature. Specifically, physical quantities, which are the ultimate properties of entities, must be expressed in mathematical symbols. Eddington in his last book, says:

> We have to express in mathematical symbolism what we think we are doing when we measure things; for if we had no conception of what we are doing, the results of the measurements would not persuade us to believe anything in particular. 49

In order to have a 'conception of what we are doing' in our physical universe, we must have recourse to the theory of group-structure. For a preliminary nnderstanding of this theory, we may turn to the following passage from his New Pathways in Science:

> Our account of the external world (when purged of the inventions of the story teller in consciousness) must necessarily be a "Jabberwocky" of unknowable actors executing unknowable actions. How in these conditions can we arrive at any knowledge at all? We must seek a knowledge which is neither of actors nor of actions, but of which the actors and actions are a vehicle. The knowledge we can acquire is knowledge

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49. Eddington, Stanley, Arthur, Fundamental Theory, Cambridge University Press, 1953, p. 265.

> of a structure or pattern contained in the actions... In mathematics, we describe such knowledge as knowledge of group-structure. 50

In continuation of the same, he writes that the words and symbols used to described the process of the universe are "the vehicles of a scheme of relationship which can be described by numbers, and so give rise to those numerical measures (pointer readings) which are the data from which all knowledge of the external universe if inferred." [51] Because of the unknowability of things, and because operations and quantities in the knower and actions in the external world need to be purged of the inventions of the storyteller in consciousness, a kind of super-mathematics is required. "Such mathematics is the theory of group-structure." [52] It is the set consisting of interlocking and interweaving of symbols in the system that is responsible for the manifestation of the external universe. Accordingly, the physical universe ultimately reaches the senses in the form of structure. [53] It is the structure, therefore, of the universe that is manifested and known rather than its nature.

From Eddington's standpoint, one properly realizes the conception of group-structure when one thinks of the

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50. Eddington, New Pathways in Science, p. 256.

51. Ibid., p. 256.

52. Ibid., pp. 256-257.

53. Ibid., pp. 262-263.

pattern of interweaving as abstracted altogether from the particular entities and relations that furnish the pattern. This manner of conceiving a group-structure in terms of a philosophical standpoint then becomes useful in scientific epistemology and in the constructinn of a philosophy of physics, as well as in the formation of an indifferent attitude toward the nature of things. Eddington was very precise concerning this point when R.B. Braithwaite charged him with claiming that a group, in the mathematical sense, is undefined except when the combining relation is given. In his answer to this charge, he was clear as to what this group-structure is in relation to knowledge. He explains:

> "Properly to realize the conception of group-structure, we must think of the pattern of interweaving as abstracted altogether from the particular entities and relations that furnish the pattern" (P.P.S., p. 141). In this abstraction the group is specified solely by the pattern; and it is essential that the combining relation C should not be 'given' since the group would cease to be abstract. This is the feature which makes the group concept useful in the philosophy of physics; for our structural knowledge of the external world gives no hint of the nature of C. What is more, it does not recognize the distinction (implied by Braithwaite) between the nature of an element and the nature of the combining relation which makes it an element of a group. The element is what it is because of its relation to the group-structure. 54

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54. Eddington, Stanley,Arthur, "Group Structure in Physical Science", in Mind, Vol. 50, No. 197, 1941, pp. 268-299.

Consequently, according to Eddington, the concept of a pure structure can only be reached by considering a pattern of interweaving, that is, a pattern of interrelatedness of relations. [55] Because of this, Eddington was able to contend that Bertrand Russell was not able to get as far as the concept of group-structure. He had only considered structure as a pattern of entities, or at most a pattern of relations.

There is certainly a development in Eddington's concept of the structuralization of knowledge and reality. With the theory of group-structure, he has moved from the mere analysis of numbers to the transphenomenal field, that is, to the abstract mathematization of knowledge and reality in terms of structures. The theory, we can readily see, was very much in accord with the subjectivism of his epistemological views.

In summary, we can see that the principal elements of Eddington's philosophical system find their ultimate roots in the physical theory of relativity and the quantum theory, with which he was so well acquainted. They provided him with the basic entities upon which his philosophy was built. These entities are: First, the physical entities which are simply the results of actual measurements. Secondly, there is the physical world which is an imaginary structure. The

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55. Ibid., p. 278.

physical quantities out of which the structure is composed constitute the indirect measures of this physical world. Finally, there is the external world consisting of entities unknowable in themselves. The physical quantities, however, are symbols of these entities and the physical world is a representation of their structure. [56] With this group-structure, we are able to eleminate individual elements that come to us through knowledge. In their stead, symbols are used, leaving the signification of these symbols to the realm of non-mathematical thought. [57] Knowledge, in the final analysis, as the starting point of Eddington's scientific epistemology, is knowledge of the group-structure of a set of sensations in a consciousness. [58]

C. PHILOSOPHICAL ELEMENT

The development of Eddington's epistemological ideas along with modern physical theories was well grounded and supported by certain philosophical tenets current at that time. They provided the principles and frames of reference in his explanation of the construction of a universe and the entities constituting it in the transphenomenal field. In his attempt to clarify the epistemological import of modern

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56. Dingle, The Sources of Eddington's Philosophy, p. 24.

57. Eddington, The Philosophy of Physical Science, pp. 141-142.

58. Ibid., p. 148.

physics and the implications of the relativity and quantum theory, he had to use philosophical tools. True, it was the principles of the relativity and quantum theory that provided him with the basis for his 'selective subjectivism' and his doctrine of structure. But it was the philosophical system of Kant, especially Kant's concept of the a priori, which provided the backbone for his epistemology.

1. KANTIAN A PRIORI

Eddington did not regard himself as a disciple of Kant, but at the same time, he acknowledged that Kant anticipated some of the ideas arising from modern physics.

> But if it were necessary to choose a leader from among the older philosophers, there can be no doubt that our choice would be Kant. We do not accept the Kantian label; but as a matter of acknowledgement, it is right to say that Kant anticipated to a remarkable extent the ideas to which we are now being impelled by the modern development of physics. 59

Eddington's epistemological interpretations of modern physical theories are similar in some important respects to Kant's views concerning the philosophical foundations of classical mechanics. Just as Kant sought to justify the principle of classical mechanics and to provide the philosophical foundations for it, Eddington in a similar fashion did the same for modern physics. Eddington's basic tools, however, were molded by scientific discoveries, and he was more

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59. Ibid., pp. 188-189.

mathematical in his approach than Kant. Nevertheless, he accepted Kantian idealism as the philosophical system within which he was to explain the epistemological implications of modern physical theory. But having accepted it, he used it in a manner adapted to his needs.

Any similarity, however, between Eddington and Kant cannot be attributed to a similarity in the logical relations of conceptual structures in classical as opposed to modern physics. Although neither relativity theory nor quantum theory has invalidated Newtonian physics, both have revealed the fact that Newtonian physics is not a universal way of description. Moreover, they have helped to define the limits of the field of application of Newtonian physics. If the similarities are not to be found in the logical relations of classical physics and of relativity and quantum theory, where are these similarities to be found? They are to be found in the field of philosophy, particularly in the approach to the problem of knowledge. The manner in which both Kant and Eddington sought to provide the justification and philosophical foundations for classical physics and modern physics is in some way strikingly similar. But the tools they used in their system were different and, likewise, their methods were different, that is, different in the manner of employing the respective conceptual schemes.

As we said earlier, Eddington recognized and accepted several Kantian tenets, insofar as they fitted into his

epistemological system. Specifically, he accepted the Kantian concept of a priori knowledge, [60] and accepted it in its recognized form. He writes:

> I think that I am using here the term 'a priori knowledge' with its recognized meaning--knowledge which we have of the physical universe prior to actual observation of it. 61

Nevertheless, Eddington makes a qualification when he adds that such an a priori knowledge, despite the fact that it is knowledge prior to any actual observation, is not, nevertheless, prior to the development of a plan of observation. Accordingly, it is a result of an "epistemological study of the procedure of observation." [62] This concept becomes a vital element of his epistemological system. It may be seen from Eddington's principle of the philosophy of science:

> ...all the laws of nature that are usually classed as fundamental can be foreseen wholly from epistemological considerations. They correspond to a priori knowledge and are therefore wholly subjective. 63

That is to say, on the basis of a priori knowledge, all the fundamental laws of physical science can be derived by pure

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60. Kant, Emmanuel, Critique of Pure Reason, translated by Norman Kemp Smith, London, Macmillan, 1958, p. 43: "In what follows, therefore, we shall understand by a priori knowledge, not knowledge independent of this or that experience, but knowledge absolutely independent of all experience. Opposed to it is empirical knowledge, which is knowledge possible only a posteriori, that is, through experience."

61. Eddington, The Philosophy of Physical Science, p. 24.

62. Ibid., p. 24.

63. Ibid., p. 57.

cogitation, without depending in any way on the results of observation and experiment. [64]

Eddington's acceptance of this concept of a priori knowledge had its consequences, in his emphasis on the function of the mind in arranging the maze of natural events according to the mind's own cannons of order. In his book, The Nature of the Physical World, he writes:

> The mind has by its selective powers fitted the processes of Nature into a frame of law of a pattern largely of its own choosing; and in the discovery of this system of law the mind may be regarded as regaining from Nature that which the mind has put into Nature. 65

Accordingly, Eddington, like Kant, affirms that the contents of the mind are determined by the mind. "The mind", Eddington says, "imposes its demands by refusing to admit any system of analysis into parts which does not yield parts with the required qualities." [66] This amounts to saying that a priori concepts are grounded within the mind's own structure. If the human mind, therefore, operates in this continuously creative manner, the one and only avenue of approach to reality for scientific knowledge in the Eddingtonian system is consciousness, the 'background' by which the physical

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64. Whittaker, Edmund, Principles of Eddington's Philosophy of Science, 5th Arthur Stanley Eddington memorial lecture, London University Press, 1951, p. 3.

65. Eddington, The Nature of Physical World, p. 244.

66. Eddington, The Philosophy of Physical Science, p. 131.

world is rendered actual.

Eddington maintained a notion of categories, comparable to that of Kant's. He spoke of these categories as the "form of thought" or, "when the form is in some degree elaborated, frame of thought." He saw them as postulates of intellectual activity, and regarded them as a "predetermined form or frame into which the knowledge we acquire observationally is fitted." [67] He makes this concept more specific by adding the word "engrained" or "primitive" denoting the fact that these concepts are somewhat innate. Some of the engrained forms of thought that Eddington considered were: Concept of the Physical Universe, Concept of Analysis, The Concept of Structure, and The Concept of Existence. [68] On this basis, he could assert that the a priori deductions stem not from the selective activity of the senses but from the frames of thought. As such, the conclusions derived shed their empirical character and take on a universality and a necessity which render the laws of science certain.

To conclude our consideration of Eddington's acceptance of the Kantian a priori, it is clear that Eddington, like Kant, conceived the problem of knowledge as a relation

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67. Ibid., p. 115.

68. Ibid., p. 135.

between subject and object. Of the two, Eddington's investigation, concentrates on the role of the subject in the process of knowledge. It would appear that Eddington, in his approach to the problem of knowledge, contended that a philosophical justification of scientific knowledge must not invoke data from empirical science, since this would presuppose perceptual knowledge as a means of acquiring data. His main concern is to arrange the parts of the process of knowledge into a logical order that will allow for the deriving of the complex from the simple in knowledge. In this manner, Eddington came to the doctrine of structure as an epistemological method of investigation. This, in turn, led to the study of frames of thought comparable to the categories of Kant. [69]

2. CAUSAL THEORY OF PERCEPTION

One of the time-honoured insights which must hold a prominent place in any sound theory of knowledge is the recognition that our cognitive experience is comprised of two elements: immediate sense-date given to the mind, and the form, construction or interpretation contributed by the mind to that data. Though philosophers generally recognize these two elements as the constitutive elements of human knowledge, they vary in their manner of seeing them in

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69. Ibid., p. 116.

operation. In this regard, Eddington is no exception. The two elements are fundamental to his whole philosophy of physical knowledge, and for him their manner of operation is seen in contemporary form in the study of what is called a 'causal theory of perception'.

Eddington's own conception of the causal theory of perception was dependent upon that of Bertrand Russell [70] and Henry Price. [71] Price maintains that the theory involves two basic factors: First, in the case of all sense-data, tactual as well as visual, 'belonging to' simply means 'being caused by,' with the result that when "M" is said to be present to my senses, this will be equivalent to saying that "M" causes a sense-datum with which I am acquainted. Secondly, perceptual consciousness is fundamentally an inference from effect to cause. [72] Bertrand Russell, likewise, affirms the same when he says:

> Whenever one complex structure causes another, there must be much the same structure in the cause and in the effect, as in the case of the gramaphone record and the music. 73

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70. Russell, Bertrand, Human Knowledge; Its Scope and Limits, New York, Simon and Schuster, 1948, and his book, On Philosophy of Science, edited by Charles Fritz, Jr., Indianapolis, Bobbs-Merrill, The Library Arts Series, 1965.

71. Price, Henry Habberly, Perception, New York, Dover Publication Inc., 1932.

72. Ibid., p. 66.

73. Russell, On Philosophy of Science, p. 100.

Russell does not explicitly term this a causal theory of perception, but speaks of it as "the identity of structure" within consciousness. In any case, for him, our knowledge of the world in physical science is nothing more than inferential knowledge and the product of the constructive activity of the mind.

In keeping with Russell, Eddington maintained, first, that we know directly only the contents of our own consciousness, that is, sense-data, and secondly, that these contents do not resemble elements of the objective world in a qualitative way. We can never be directly conscious of anything except sense-data as constituted in the content of consciousness. "Mind", he says, "is the first and most direct thing in our experience and all else is remote inference--inference either intuitive or deliberate". [74]

The causal theory of perception sees perception as a basic organic activity at the level of the surface receptors of a percipient organism. It reduces sense-data to mere effects which are taken as the evidence for the perception of something constructed by perceptual activity. Accordingly, it sees sense-data as nothing more than qualitative impressions. From this, it is clear that the causal theory seeks to interpret the physical world in terms of the data available within the observer's own experience.

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74. Eddington, The Nature of Physical World, p. 281.

One of Eddington's favorite ways of explaining the causal theory of perception is to depict the brain as a great telephone exchange center and the nerve fibres as wires extending from this center to the edge of an external world.[75] This enables us to see more clearly the chain of events that occurs in perception. There is a mental process followed by a selective activation of some receptors which receive the coded afferent messages. These receptors bring these messages to the central neuronal system which correlates mental events and decodes the messages received. This mechanistic interpretation sees perception purely in terms of physiology according to which physical objects must be coded into signals, transmitted and altered along the nerves of the brain. Within this interpretation, the mind, nevertheless, is assured of its capacity to know physical objects.[76]

Eddington's acceptance of this causal theory of perception led him to conclude that the so-called secondary qualities of material entities, such as colors, the pitch of sound, smoothness, etc., are mental and not material characteristics. The secondary qualities are purely subjective, that is, they exist only in the mind of the observer. The knowledge acquired about the material universe depends on the

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75. Ibid., p. 227.

76. Eddington, Arthur Stanley, "Physics and Philosophy", in Philosophy, Vol. 8, No. 29, January 1933, p. 32.

properties of the receptors and the nervous system. The material universe which we construct, infer, or postulate will be determined and limited by these properties. Accordingly, the observer does not experience objects directly but only the effects within him of the objects.

With respect to his conception of two worlds, namely, a familiar world and the physical world, Eddington found that the causal theory can explain the appearance/reality distinction by pushing all sense-data into the mind to become the only content of consciousness. With the observer as the center and measure of all things, every material characteristic of bodies became a mental construction through which the external world is made known and present to consciousness. We do not know objects directly but only their effects which are produced in the brain by way of a series of physiological changes before an object is decoded as representing, for example, a man or a stone.

In brief, the causal theory of perception, upon which Eddington's philosophy stands, can be stated as follows: In perception, we only perceive sense-data which are pure effects of entities upon the brain. These effects are the sole content of consciousness. They are ordered in a structural pattern which travels to the brain through the complex network of nerves in the form of signals after the manner of a code. As they reach the brain, they are decoded and expressed with symbols in mathematical formulae.

Fundamental to this understanding of the knowing process is the viewing of sense-data present in consciousness as effects of entities in the physical world. This view of sense-data prevails throughout Eddington's exposition of his doctrine of structure and his theory of knowledge.

Viewing the causal theory of perception critically, we see it beginning in doubt with respect to the certainty of the physical world. Subsequently, a mental world comes into being which may or may not correspond to external physical objects. In the final analysis, knowing is seen to be founded on those inner events which seem able to know only themselves. [77] On the other hand, we can see it as commencing immediately with an awareness of a sense-datum, not knowing what the object actually is that is perceived, and moving through a process toward the development of a representation of the physical object. This is called by Rodrick Firth the "discursive inference theory of perception". [78] It involves always a sensation and a subsequent act of judgment within consciousness. In this understanding of the theory, physical objects are knowable simply on the basis of their being reducible to objects of direct awareness. In Eddington's terms, these are sense-data; they constitute the first and most direct thing in our experience.

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77. Sellars, Roy Wood, The Philosophy of Physical Realism, New York, Russell and Russell, first published in 1932, 1966, p. 40.

78. Firth, Rodrick, "Sense-data and the Percept Theory", in Mind, Vol. 58, No. 232, October 1949, p. 443.

3. OPERATIONALISM

Owing to the observational character of Eddington's theory of knowledge and the structuralization of its processes in terms of symbols, he maintained an operational viewpoint throughout the whole exposition of his philosophy. This viewpoint no doubt reflects the scientific habitus of Eddington. It is manifested most in his doctrine of structure and in his theory of group-structure consisting of a set of operations. This operationalism is typical of the methods of science, especially in the construction of its abstract conceptual schemes where it uses symbols that are fixed within a system constituting sets of operations. Furthermore, when Eddington conceived the physical universe as the interlocking of relations and symbols, or a pure structure, the concept of operation in relation to the meaning of symbols necessitated this operational viewpoint. He had to maintain this attitude in order to explain that the meaning of a symbol within the system is synonymous with a set of operations that enable the observer to decide whether or not the symbol is correctly applied and whether this symbol is meaningful within the system.

In relation to Eddington's system, operations are non-physical. These operations are mentally expressible in terms of function, usually a symbol. As such, they exhibit a world in which free inventions are possible, and are capable directly or indirectly of being connected with instrumental

operations. [79] These operations in the context of knowledge become identified with any act which is performed with a view to the production of symbolic knowledge, or to its improvement in clarity and certainty. [80]

The doctrine of operationalism permitted Eddington to give a symbolic character to his entities in the physical world, thereby enabling them to be known within consciousness as sense-data and permitting the entities and pointer-readings to be used as devices for communication. Physical quantities, one of the basic entities upon which Eddington's philosophy is built, together with operationalism, reveal to us the world-condition as structures, describable in terms of mathematical symbolism. Eddington, in his earlier book, The Mathematical Theory of Relativity, summarizes his position as follows:

> The study of physical quantities although they are the results of our own operations (actual or potential), gives us some kind of knowledge of the world-conditions, since some operations will give different results in different world conditions. It seems that this indirect knowledge is all that we can ever attain, and that it is only through its influences on such operations that we can represent to ourselves a 'condition of the world'. Any attempt to describe a condition of the world otherwise is either mathematical or meaningless jargon. To grasp a condition of the world as completely as it is in our power to grasp it, we must have in our minds

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79. Benjamin, Cornelius, Operationism, Springfield, Charles Thomas, Publishers, 1955, p. 93.

80. Ibid., p. 119.

> a symbol which comprehends at the same time its influence on the results of all possible kinds of operations. 81

Moreover, the operational character of physical knowledge in the Eddingtonian system explains the relativity of things as observed by the observer because they are always modified by the operations whereby the observer observes them. [82]

Generally, operations involved in a set of operations constitute the following: 'First, a discriminating process which involves the creation of symbols; secondly, an association which involves the combining of particulars for the purpose of symbolic representation into complex objects; thirdly, a generalizing which includes the formation of concepts and general laws; fourthly, an ordering, where symbols are defined to represent a particular class, and symbols for a series are devised and given meaning'. [83] All these elements play a vital role in Eddington's doctrine of structure, especially in his theory of knowledge and in his attempt to solve the dualistic problem of matter and consciousness, as well as the dualism within reality itself considered in itself and as known.

Eddington's operationalism is manifest in the following:

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81. Eddington, Arthur Stanley, The Mathematical Theory of Relativity, Cambridge University Press, 1923. The quote was taken from the 1960 reprint by the same publisher, p. 3.

82. Lovejoy, op. cit., p. 362.

83. Benjamin, op. cit., pp. 124-133.

> ...I must insist that I am rescuing out of the mathematical formalism what is for physical purposes the most essential feature of the group conception of structure, namely, that primarily the elements of a group (or ring or algebra) are defined solely by their role in that group (or ring or algebra) 84

The elements within the group are elements insofar as they have functions or a role to play within the group-structure. They are defined and identified by means of their structural role within the group-structure. Consequently, the sphere of the meaningful is restricted by the strict operational method of definition of the elements within the structure.

His operational approach and his acceptance of the causal theory of perception emerge as his means of explaining our knowledge of objects in the physical world. It provided him with the necessary instruments for the structuralization and symbolic interpretation of knowledge. His operationalism guaranteed symbols to mean the same as the set of operations, and guaranteed the applications of these symbols to be correct and meaningful. His causal theory of perception provided him with the structural explanation of the process of knowing within consciousness in terms of the physiology of the brain. Given knowledge as structured, he was able through the concept of operation in terms of sets to assign symbols to the effects, namely, sense-data, in consciousness, and thereby was able to

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84. Eddington, "Group Structure in Physical Science", in Mind, Vol. 50, No. 197, 1941, p. 269.

express knowledge in terms of mathematical symbolism. In an article written in 1933 in Philosophy, he indicated how operationalism and the causal theory of perception work together, especially in making the observer aware of objects of the physical world. He wrote:

> We are cognizant of an object in the physical world only insofar as it broadcasts light waves, or pressures, or similar signals through an intervening medium. These signals are transmitted in altered form along the nerves to the brain. All the characteristics of physical objects must be coded into signals of this form before the mind has the chance of becoming acquainted with them...
>
> We only get to know of their existence by the usual circuitous route, by light waves, etc. leading to the extremities of nerves, then along the nervous system to the brain. 85

There were, of course, other forces and philosophies that contributed to and helped shape Eddington's philosophical system. Some of these forces stemmed from his social and religious background, concentrated especially in the tensions between religion and science, which had become a prevailing topic of the day. [86] The influence of logical positivism is evident in his own allusions to it when he explains the

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85. Eddington, "Physics and Philosophy", in Philosophy, Vol. 8, No. 29, January 1933, pp. 32-33.

86. Eddington himself engaged in long discussions concerning the question of God and the Universe, the question of mystical religion and the concepts of physics, religion and the scientific approach. His positions on these questions posed by his contemporaries, both those advocating fideism and scientism, can be found in, Cohen, Chapman, God and the Universe, London, The Pioneer Press, 1931, chapters 2-4.

observational verification of quantities of physics in physical knowledge. [87] Likewise, he was influenced by his association with prominent physicists, mathematicians and philosophers, such as Herbert Dingle, a physicist-philosopher, Edmund Whittaker, who edited his last book Fundamental Theory, Bertrand Russell, C.D. Broad, R.B. Braithwaite. All of these were among the many men with whom he discussed and argued, and all of whom made contributions and lasting influences to his philosophical system. Our own choice, however, of the factors that helped shape his philosophy is based upon what we considered to be the most relevant to the dominant elements in his system, and the most influential with respect to the whole of his thought.

Given our choice of the scientific and philosophic factors that helped shape his thought, Eddington could hardly have avoided a subjectivist position in philosophy. Moreover, it was a logical outcome of his own thought. If he was to remain faithful to his initial starting-point and to his premises, he had to succumb to the notion of the structuralization of a universe and to the structural process in obtaining knowledge of the physical universe. The tension between the world presented by physics and the world presented

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87. Eddington, The Philosophy of Physical Science, p. 189.

by common sense is evident in his writings.[88] He ventured into the depths of the structure of thought and tried to find a method and a means whereby he could harmonize these two worlds, and simultaneously justify both as valid and viable in the realm of knowledge. In doing this, he arrived at the concept of structure which fitted his selective subjectivism as an explanation of the appearance/reality distinction, the world of physics and familiar world dichotomy, and the dualism of matter and consciousness. This concept eventually became a method and a principle in explaining a whole theory of knowledge which could bring together the apparent epistemological dualism of reality and mind. His philosophy reduces physical knowledge to a type of structural pattern in the observer's mind, whose sole activity is building and constructing the sense-data present in consciousness. In order to build a world which is purely mental, one needs a principle to connect all the effects or sense-data present within consciousness. For Eddington, the doctrine of structure served the purpose well. In the structuralization of knowledge, sense-data are expressed as symbols. These symbols become the matter of the physical universe and form the apparent structure of the external world, about which in the final analysis we know nothing.

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88. We are referring to his philosophical books, namely, The Philosophy of Physical Science, The Nature of the Physical World, and New Pathways in Science.

CHAPTER III

DOCTRINE OF STRUCTURE IN PHYSICAL KNOWLEDGE

INTRODUCTION

The preceding chapter sought to expose the major determinants that provided the occasion and ground for Eddington's philosophy. We saw that the theory of relavitity and the quantum theory became so much a part of him that his philosophical thought must in large measure be viewed against the background of the new physics. Before elaborating Eddington's doctrine of structure, it is necessary to clarify further this philosophical thought as it took shape in the world of the new physics. The scientific epistemology that emerges will provide us with the context within which to channel the rationale of his doctrine.

From 1928 to 1939, the respective dates of publication for The Nature of the Physical World and The Philosophy of Physical Science, Eddington attempted to work out an interpretation of physical science which would combine the philosophical implications of relativity and quantum theory, namely, subjectivism and operationalism, with the causal theory of perception and its concomittant notion of a non-sensible real world. The knowledge proper to physical science "takes the form of a detailed description of a world - the

so-called physical universe". [89] Since the epistemology related thereto deals only with that type of knowledge arising from the methods of physical science, Eddington sees it as a sub-branch of the science of epistemology, "that branch of philosophy which treats of the nature of knowledge". [90] For this reason, he terms the knowledge acquired by the methods of physical science "physical knowledge". [91] Scientific epistemology is, accordingly, the epistemology of physical science. [92] Now physical science deals with sets of pointer readings, and their relations and connections with other pointer readings, [93] operating within the conceptual frameworks of structure and function, underlaid specifically by mathematical structures. [94] Consequently, Eddington's doctrine of structure or "structuralism" constitutes a sub-discipline of his scientific epistemology, a principle of explanation and a method of acquiring knowledge of the physical universe. Likewise, it will become apparent that his "selective subjectivism" is another sub-discipline.

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89. Eddington, The Philosophy of Physical Science, p. 1.

90. Loc. cit.

91. Ibid., p. 2.

92. Ibid., p. 5.

93. Eddington, The Nature of the Physical World, pp. 252, 254, 304, Cf., Eddington, The Philosophy of Physical Science, p. 100.

94. Wartoffsky, op. cit., p. 95.

What does Eddington mean by "structuralism"? First of all, it should not be identified with the structuralism advocated by the present-day Parisian School as a reaction to existentialist thought. This more recent structuralism is a humanism based on the technical notion of structure developed in two limited fields of research, namely, Linguistics and Cultural Anthropology. [95] As a methodological system of explanation, it advocates an approach to human problems that constitutes an antidote to the dehumanization of our age, when man, dominated by science, technique, and the machine, is ceasing to be a subject and is turning into an object.

Though Eddington shares these humanist views, his structuralism is more allied with the general recognition of structure in all knowledge. Since form and structure reveal themselves on every level of experience, any philosophy or any knowledge which regards these notions as basic could call itself "structuralism". [96] For Eddington, structuralism is not a system constructed to refute a certain kind of philosophy or a scientific theory. It is, instead a system resulting from the philosophical implications of relativity and quantum theory. It is designed as a method to resolve

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95. McNicholl, Ambrose, "Structuralism", in The Irish Theological Quarterly, Vol. 35, No. 3, July 1968, (New Series 1951), pp. 235-236.

96. Ibid., p. 236.

the problem brought about by these theories in the domain of epistemology, namely, the problem of dualism between what we know as existing "out-there" and as existing in our minds. The subjectivism and operationalism within scientific epistemology, which Eddington attempted to combine with the causal theory of perception, demand a structural approach because of the very criterion of selectiveness with respect to the instruments used by the observer, whether they be sensory or intellectual, or the instruments used in physical operations such as tensors. Eddington's structuralism is mainly a method of explanation in resolving the aforementioned epistemological dualism of mind and reality as well as the consequent metaphysical dualism of reality, namely, the dualism of the thing itself and the thing as known. In addition, Eddington's structuralism becomes a principle of organization and correlation with respect to sense-data acquired by the observer's instruments in the process of observation.

Eddington, in trying to give a name to his philosophy, says he would hesitate between "selective subjectivism" and "structuralism". He added, however, that the latter refers to the more mathematical conceptions of his philosophy.[97] If physical knowledge is a knowledge of a detailed description of the physical universe acquired by the observer's instruments,

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97. Eddington, The Philosophy of Physical Science, pp. vii-ix.

then "structuralism" describes more accurately a physical universe the structure of which comprises what is called the "external world". Structuralism is not, of itself, to be identified as a philosophy, but rather as a scientific movement that has developed within the physico-mathematical interpretations of the logical constructs of the mind in an effort to construct a physical universe. Because it employs philosophical tools and concepts, it is, to a certain extent, philosophical in nature, and accordingly, can be analyzed in part through the methods of philosophy and philosophical thinking. The fact that it subscribes to certain philosophical doctrines and concepts, renders it subject to philosophical scrutiny.

Eddington's insight into the potentialities of structuralism within scientific epistemology led him to the heart of the dualistic problem. He saw that through structuralization of the data of consciousness, we are able to abstract certain properties from a given range of phenomena and to establish definite relations between the properties in terms of symbols and a set of operations. This structuralism is modeled upon the structure of symbolic algebra and logico-mathematics with their concepts of inclusion and abstraction. In keeping with this model, the formation of concepts within structuralism is very arbitrary, with the result that one can manipulate the meanings of the symbols at one's own discretion; they can be fitted within a frame of thought at will.

Structuralism finds its full expression in physical science as "a closed system, a cycle of mathematical relations among measurements, an affair of relations between pointer readings".[98]

For further appreciation of Eddington's doctrine of structure, we must see it within the whole context of his thought. Toward this end, let us dwell on his conception of the world, along with his concept of selective subjectivism and his understanding of physical knowledge generally.

In the introduction to The Nature of Physical World, he speaks of the world as twofold: First, a familiar world, which, along with possessing extension and color, is above all substantial; secondly, a scientific world which is for the most part empty, composed only of numerous electric charges sparsely scattered and rushing about with great speed.[99] The familiar world of everyday experience is very largely a creation of the mind consisting of sense-data. It is a world that the observer builds within his mind. "In general," Eddington says, "we should describe the familiar world as subjective and the scientific world as objective".[100] In the familiar world, the secondary qualities are essentially subjective; they are mere "mind-spinning". "The familiar world is the world of trees, chairs, tables, and the common

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98. Edman, Irwin, "Charting the Mazes of the Modern Physical World," in The New York Times, May 5, 1950, p. 13-K.

99. Eddington, The Nature of the Physical World, pp. xi-xii.

100. Ibid., p. 94.

things of daily life". "The beautiful hues which flood our consciousness under stimulation of the waves have no relevance to the objective reality," [101] which constitutes the physical world. Dr. Stebbing, in her critique of Eddington's philosophy, says:

> Eddington thus seems to regard the familiar world as a story, constructed by the perceiving part of my mind out of messages received from the external world. 102

The familiar world is a construction of the mind built by means of the sense-data transmitted along the nerves. These are Eddington's actual words:

> In fact, the mind has also invented a craft of world-building; its familiar world is built not from the distribution of relata and relations but by its own peculiar interpretation of the code messages transmitted along the nerves into its sanctum. 103

In brief, the familiar world is a delusion, spun by the mind of each of us for himself under the mistaken impression that he is just translating messages from the external world. [104]

On the other hand, Eddington equally posits a

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101. Ibid., p. 94.

102. Stebbing, Suzanne, Philosophy and the Physicist, New York, Dover Publications Inc., 1958, p. 102.

103. Eddington, The Nature of the Physical World, p. 240.

104. Broad, C.D., "Review of L.S. Stebbing's book, Philosoand the Physicist", in Philosophy, Vol. 13, 1938, p. 223.

scientific world, [105] a world built by physics. It is a shadow-world, shadowing a world familiar to our consciousness. It shadows impressions which can be traced to the external sense-organs. [106] This world consists of electric charges and is constructed of electrons, protons, positrons, electromagnetic waves, etc.,; there is nothing substantial about it. [107] It is a world proper to Eddington's conception of physical science, namely, a world of symbols representing commonplace experiences. [108] The physical world, according to Eddington, is a complex of metrical symbols which are mere shadows of the familiar world. The physical world revealed by physics is not a continuous substance, but a host of tiny electric charges called electrons and protons "darting hither and thither with inconceivable velocity". [109] It is a world of point-events with their primary interval relations, or a world of relations between point-events that can be described mathematically. [110] In summary, the world of physics

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105. The terms "scientific world", "world of physics", and "physical universe" will be used interchangeably. Cf. Eddington, The Philosophy of Physical Science, p. 159: "There is no difference between the physical universe and the universe of physics".

106. Eddington, The Nature of the Physical World, p. 110.

107. Ibid., p. xii.

108. Ibid., p. xv. The relevant task for philosophy falls to an epistemology of science that attempts to bridge the gap between physics and common sense.

109. Eddington, New Pathways in Science, p. 1.

110. Eddington, Arthur Stanley, Space, Time and Gravitation, An Outline of the General Theory of Relativity, Cambridge University Press, 1920, pp. 197-198.

is a world of electrons and protons, measurements, pointer readings, a world revealed solely by the structural nature of physical knowledge, depicting a universe that is pure structure. It is a world of observable, measurable and calculable elements, considered not as hypothetical entities, but as real or actually existing. [111]

Beyond the world known to physics, lies the external world. The external world is the background to the measures, a substratum where measures in the physical world find their existence. Outside of these measures, the external world is inscrutable to scientific inquiry. The external world is like the Kantian noumenon, the thing-in-itself, which we cannot know. It is introduced by Eddington to account for the similar patterns of interlocking sensations in different individual experiences. Its usefulness lies in its capacity to bring together the world of many consciousnesses occupying different viewpoints. As such, the external world becomes a neutral ground or an element studied by man that is common to every consciousness. [112] Later, in his book, The Philosophy of Physical Science, he elaborates upon this notion of the external world. "This real," he says, "outside individual

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111. Stace, W.T., "Sir Arthur Eddington and the Physical World", in Philosophy, Vol. 9, No. 33, January 1934, p. 39.

112. Eddington, The Nature of the Physical World, p. 284. Cf. Yolton, John, The Philosophy of Science of Arthur Stanley Eddington, Martinus Nijhoff, The Hague, 1960, pp. 54-55, 112.

consciousness, where the common causes of the sensory structures in different consciousnesses are located, is called "the external world"." [113] The original sensory structure which occurs in many different consciousnesses is located in the external world. It is a consequence of the regularities, underlying the sense-data and appearing in the minds of all men. As such, it constitutes a scheme linking together different minds. [114] Nothing can be said about the nature of this external world, save that it contains entities capable of sending messages along the nerve fibres. All that physical science can assert concerning the external world must be inferrable from the signals that arrive at the brain. "Unless they come in the form of nerve signals, they cannot be part of our conception, and therefore must be excluded". [115]

Not only must we relate the world of physical science to the external world, but we must also relate it to the familiar world as well. The scientific and familiar worlds are just two aspects, or two interpretations, of one and the same world, that must be identified in some manner. The "whole scientific inquiry," Eddington says, "starts from the familiar world and in the end it must return to the

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113. Eddington, The Philosophy of Physical Science, p. 209.

114. Eddington, "Physics and Philosophy", in Philosophy, Vol. 8, No. 29, 1934, p. 34.

115. Eddington, New Pathways in Science, p. 4.

familiar world". [116] The question is, how can this be achieved? Admittedly, the process by which the world of physics is translated into a world of familiar acquaintance in human consciousness is outside the scope of physics. But since Eddington insists that science aims at constructing a world symbolizing the world of commonplace experience, science must be directed in part toward laying the foundation for this translatinn. Moreover, Eddington's symbols play a double role in the realm of knowledge; scientific knowledge symbolizes both the familiar world of common sense and the external world. It is here that Eddington's doctrine of structure enters the picture. He formulated this doctrine as a way of showing the objectivity of science, of showing how the scientific story does reveal some information concerning the external world. In short, he strove by means of this doctrine to establish the union between common sense and science, between the world of everyday experience and the world of physics, [117] between the thing itself and the thing as known, between the objective world as existing "out-there" and as existing in our minds. Apart from its relatedness to an external world, the doctrine of structure is, first of all, a kind of half-way house, or a connecting

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116. Eddington, The Nature of the Physical World, p. xv.

117. Yolton, John, The Philosophy of Science of Sir Arthur Eddington, Netherlands, Martinus Nijhoff, The Hague, 1960, p. 44.

link between physics and ordinary experience. Eddington maintained that physics must remain faithful in some measure to the beliefs and interpretations of common experience. He saw physics as dependent upon ordinary perceptual experience for its data. In other words, physics must start from what Bertrand Russell calls "momentary empiricism", that is, from experience. [118] The doctrine of structure belongs to this context of interplay, between physics and common experience. Before unravelling the role of structure in this interplay, it is necessary to proceed with our analysis of the meaning of structure itself.

CONCEPT OF STRUCTURE

The notion of structure is no newcomer to academic disciplines, whether they be in the field of science or philosophy. It is closely related to the notion of form, which was central to the philosophy of Plato and Aristotle, as well as to the science of the Pythagoreans. John Yolton speaks of structure as playing a role similar to the Scholastic concept of form, insofar as form was considered to be that whereby the external world is known. [119] Benedict Ashley sees structure and function as the modern scientific equivalents of the Aristotelian four causes when he says:

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118. Ibid., p. 30.

119. Ibid., p. 53.

> What is called structure (with its correlative 'composition' and 'organization') is the material and formal causes. What is called the function (with its correlative 'agent' and 'product') is the efficient and final causes. 120

It is not surprising that modern philosophy and science continue to make use of the notion of form. This notion is natural to the mind, since the mind seeks to reduce the multiplicity of the given to a unity, and the concept of unity contains the most generic notion of form or order. [121]

Eddington, as a philosopher-physicist, is, of course, more interested in the modern scientific equivalent of form, namely, structure. For him, structure is a network of interconnected symbols which are allocated to entities and objects of the external world. These symbols are weaved, connected, and interrelated by the operational and functional symbols [122] invented by the mind. They provide the key for an understanding of the reality of the external world.

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120. Ashley, Benedict, "Does Natural Science Attain Nature or only Phenomena?", in St. John University Studies, p. 73.

121. McNicholl, "Structuralism", in The Irish Theological Quarterly, Vol. 35, No. 3, July 1968, p. 235.

122. These operational and functional symbols within a system consisting of structure are similar to those used in matrix calculus, for example, symbols like -, $+$, $\dagger$, the summation sign , the inclusion sign $\subset$, the universal sign $\vee$, etc. These symbols are said to give meaning to a certain structure and render the non-mathematical symbols meaningful when they are referred to reality attained by physical knowledge.

Networks of symbols do not themselves necessarily involve mathematical conceptions and, accordingly, do not necessarily render the subject mathematical. In view of this, structure is conceived simply as a principle of organization within a system whether it be a closed or open one. [123] The concept of structure in reference to the physical universe can then be stated as follows: We allocate symbols A, B, C, D, etc., to entities or qualities as messages received from the external world and impinging on the nerve fibres. Thereupon, a type of comparison or relation is introduced between these symbols. In order to allow for changes, whether the changes consist in alterations of object or quality, it is necessary to introduce operational and functional symbols which make the relations between the original symbols possible. After this is accomplished, we have a system with its own set of entitative or qualitative symbols as well as sets of operative or functional symbols. The system, accordingly, is composed of a set of different entities or qualities, with a thoroughly organized network of relationships. In other words, Eddington's conception of structure appears to be a pattern of relations, or more accurately, a pattern of interrelatedness of relations.

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123. By closed system, we mean a collection of symbols which are solely referential. The symbols therein have no other function than being a reference. They are meaningful only in their referential status. In a closed system, one can formulate definite rules in such a system. On the other hand, an open system is a collection of symbols which have reference to other things outside the structure, not merely referential.

Eddington, nevertheless, due to his scientifico-mathematical inclinations was not satisfied with this state of the doctrine. If left at this stage of development, he says that we would find ourselves going on "in an orgy of notation, introducing more and more symbols, but never getting beyond notation". [124] One must put a stop to the infinite regression of symbols, if mathematical thought is to be introduced. This infinite regression is prevented by what are called "terminable sets of operations". He writes as follows:

> We see therefore that there exist "terminable sets of operations" which do not lead to a regression of nomenclature of ever-increasing complexity. It is only through such terminable sets that mathematical thought can be introduced. To the extent to which the various portions of our experience can be related to another in terms of these operations they form material for mathematical treatment. 125

With the regression halted by terminable sets of operations, the way has been prepared for an understanding of structure in terms of 'group'. Any mathematical description of the group "specifies only the pattern of the interlacing, and pays no attention to the physical nature of the operations which yield this pattern". [126] Accordingly, mathematics becomes a means of describing the group-structure of the

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124. Eddington, The Philosophy of Physical Science, p. 138.

125. Ibid., p. 140.

126. Ibid., p. 140.

elements of our knowledge. We describe the pattern of interweaving, which is abstracted from particular entities and relations, in mathematical terms. Consequently, this pattern of structure, abstracted from the particular entities and relations, becomes what he calls the mathematical concept of structure, since, "it can be exactly specified by mathematical formulae". [127] The function of mathematics is to elucidate the group-structure of the elements involved in a symbolic and structural knowledge. Its function is to described the pattern of interweaving and interlocking of operations, in order that knowledge might be communicable and capable of manifesting the external world. Implicitly, this entails a recognition of structure in the external world as well as in consciousness. As Eddington says, "all that physical science reveals to us in the external world is group-structure, and group-structure is also to be found in consciousness". [128]

What kind of entities constitute the structure from which the pattern of interweaving or symbolic configuration is abstracted? It is the kind that belongs to matter in motion, discrete packets of energy, and physical objects as conceived by the mind. These entities are the constituents of a physical world that is in the final analysis a pure

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127. Ibid., p. 142.

128. Ibid., p. 150.

structure. This physical world can only be known to us, if our knowledge itself is structural. In addition, our method of acquiring knowledge must be according to structures and structural processes. If that which we know is structure, then somehow, concepts which are the instruments of acquiring knowledge of the external world, must, themselves, be structural. Not only that, but sense-data, as objects of perception presented in consciousness, must necessarily be structured. [129]

DOCTRINE OF STRUCTURE IN EDDINGTON'S THEORY OF KNOWLEDGE

Marx Wartoffsky in treating the nature of physico-mathematical knowledge writes:

> In the flush of success of the mathematical description of the physical world, in the 17th century, Spinoza could express the correspondence of thoughts and things as an identity: "The order and connection of thoughts is the order and connection of things". In effect, our construction of a rational conceptual representation of the world corresponds to the way the world is, because reason, which is exemplified in mathematical reasoning, also exemplifies world structure itself. 130

This one-to-one correspondence of thought with things, suggested by Wartoffsky, is quite removed from Eddington's theory of knowledge. For Eddington, the order and connection of thoughts in consciousness constitute the actual order and connection of things. This identity of thought and reality is supposedly

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129. Ibid., p. 147.

130. Wartoffsky, op. cit., p. 15.

made possible through the doctrine of structure, which would thereby resolve the problem of the validity of knowledge and the problems of epistemological and metaphysical dualism. Likewise, Eddington uses the doctrine of structure to explain the inference from percepts to causes. Moreover, if knowledge from measurements is knowledge describing a structure called the 'physical universe,' the description must be communicable.

This communicability stems from structure, made possible by the methods of symbolic algebra. [131] The symbolic algebra involved is an algebra of measurements based on pointer readings, and pointer reading percepts relate to the external world. Pointer reading percepts form the basis for constructing a structural knowledge of the external world. Accordingly, structural knowledge, in turn, is enabled to form the means through which the mind becomes acquainted with the external world. Since this world is in the final analysis, inscrutable and unknowable, we must settle for a structure that is abstract, and this abstract structure is best described by symbolic algebra. Eddington, in the later development of his thought as found in his book, Fundamental Theory, advances his position in these words:

> Our mode of acquaintance, through sense organs, with a world external to the individual mind is such that our knowledge of

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131. Slater, Noel, The Development and Meaning of Eddington's 'Fundamental Theory,' including a compilation from Eddington's unpublished manuscripts, Cambridge University Press, 1957, p. 277.

> it is necessarily structural knowledge; and our only means of describing abstract structure, when that which possesses the structure is unknown, is provided by the methods of symbolic algebra. These represent a structural pattern by the interrelations of a closed group of symbolic operations. The entity and its attributes, being elements of this structure, cannot be represented otherwise than by symbols. 132

In terms of structural knowledge, it is evident that the only entities that have meaning are measurables. [133] These measurables are weaved into a network of mathematical relations that formally constitute the physical universe, - a universe that is a pure structure known to the scientific mind through structural knowledge.

With this preliminary understanding of Eddington's doctrine of structure, we are now in a position to examine more fully the role it plays in physical knowledge. Eddington defines physical knowledge simply as that knowledge acquired by the methods of physical science, that is, by observation, measurements, and experimentations, the content of which is identifiable with the "contents of certain encyclopaedic works, such as the Handbuch der Physik". [134] Bearing in mind the

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132. Ibid., pp. 280-281.

133. Eddington, The Nature of the Physical World, pp. 252-253. Also, Cf. Maritain, Jacques, The Degrees of Knowledge, newly translated from the fourth French edition under the supervision of Gerald B. Phelan, New York, Charles Scribner's and Sons (copyright by Jacques Maritain, 1959), p. 61.

134. Eddington, The Philosophy of Physical Science, p. 2.

question of the degree of certainty that attaches to physical knowledge, [135] he goes on to speak of this knowledge as "that which a right-thinking person would to-day accept as justified by physical science". [136] To understand the nature of physical knowledge in its essential aspects, we must recognize that it, as a description of the world, must possess in itself the formal character of that description. The world it describes is the physical universe, conceived as a "theme of a specified body of knowledge," conceived, that is, as structure. Accordingly, for Eddington, the description of the nature of physical knowledge is logically prior to an understanding of the physical universe. In the face of this epistemological approach, science "takes knowledge as its starting point rather than an existent entity of which we have somehow to obtain knowledge". [137] The foundations of physics are thereby freed from the suspicion of metaphysical 'contamination,' insofar as the physical universe and the physical objects which constitute it are reduced to the 'theme of a specified body of knowledge'.

Another essential aspect of physical knowledge is its character as observational; it is a knowledge based upon observation.

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135. The assessment of the certainty of knowledge is to be regarded as separate from the study of the nature of knowledge, Cf. Witt-Hansen, op. cit., p. 33.

136. Eddington, The Philosophy of Physical Science, p. 2.

137. Ibid., p. 3.

> Every item of physical knowledge must therefore be an assertion of what has been or would be the result of carrying out a specified observational procedure. [138]

Since some items of physical knowledge, however, have not been tried before the 'court of appeal' of observation, Eddington concedes that this knowledge might better be described as 'hypothetico-observational'. [139]

In addition to these aspects, physical knowledge, if it is to be a knowledge that truly describes the physical universe, must be communicable. Since its communicability belongs only to structures, physical knowledge must necessarily be a structural knowledge. This structural knowledge, insofar as it is structural, is expressible in mathematical form. When we know something in the physical world, it is not the thing that we know, but rather its structures which are in our consciousness. For this reason, Eddington sees the knowledge of structures as distinct from the knowledge of the entities forming the structures. It is possible, therefore, to have a knowledge of something independently of its entitative character because "so long as the knowledge is confined to assertions of structure, it is not tied down to any particular realm of content". [140] This helps to clarify further what was said earlier, namely, that the pattern of

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138. Ibid., p. 10.

139. Ibid., p. 12.

140. Ibid., p. 143.

interweaving abstracted from the particular entities and relations which furnish the pattern, makes it possible to know the external world beyond the particular content of the mind. These patterns constitute what Eddington calls 'structural knowledge'.

Moreover, Eddington maintains that percepts, which are causally removed from their supposed objects in the external world, are related to them through structure. Likewise, the formalized mathematical knowledge of the exact sciences that seeks to describe with accuracy the physical world is related to that world through structure. Finally, it is through structure that the belief of common sense in an independent external world is justified.

Eddington sees structure as fulfilling this key role in knowledge, insofar as he regards the investigation of the external world as a quest for structure, considered as a complex of relation and relata. In one of his earlier books he wrote:

> The investigation of the external world is a quest for structure rather than substance. A structure can best be represented as a complex of relations and relata; and in conformity with this we endeavor to reduce the phenomena to their expressions in terms of the relations which we call intervals and the relata which we call events. 141

Not only is structural knowledge grounded in the

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141. Eddington, The Mathematical Theory of Relativity, Cambridge University Press, 1923, p. 41.

structures of the external world, but it is built from concepts in our familiar experience. Although the epistemological approach commences with the examination of scientific knowledge, structural knowledge originates from 'general concepts,' which are nothing else than concepts describing things in the familiar world. A general concept "is our conception of what the symbol represents in our ordinary non-mathematical form of thought". [142] It lacks the precision of a mathematical concept. A structural concept does not include the whole of a general concept, but only that portion which can play a role in the formation of group-structures. The structural concept is the concept that remains after the elimination of the general aspects of the general concept. A structural concept can then be defined and obtained, as Eddington says:

> from a corresponding general concept by eliminating from our conception everything which is not essential to the part it plays in a group-structure. It is an element in a specified pattern without any properties except its connection with the pattern. Its properties are those of a mathematical symbol, which consist solely of its associations (or, more strictly the associations of its associations) with other symbols...As a structural concept the part is a symbol having no properties except as a constituent of the group-structure of a set of parts. 143

How, then, does structural knowledge enable Eddington to affirm that the order and connection of thought is the

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142. Eddington, The Philosophy of Physical Science, p. 144.
143. Ibid., pp. 144-145.

order and connection of things? How can Eddington say that the structures as percepts are the basis for inferring objects in the external world? Although we cannot know the intrinsic nature of a thing nor the nature of the external world, something in the physical world must, nevertheless, provide the observer with a percept. This 'something' is structure, insofar as the physical world consists of pointer readings rendering it purely a structure.

Accordingly, all our perceptions are perceptions of structures in the physical world. These structures outside the mind are one with the structures inside. The content of my consciousness is the pattern of interweaving of sense-data or a structure intimated by the external world. Moreover, in terms of the causal theory of perception, the observer does not experience directly the objects but only the effects of the object in him. These effects are actually the network of sense-data present in consciousness. In the knowing process, knowledge of our environment comes to us in the form of messages transmitted along the nerves to the seat of consciousness. [144] That which is actually known is the effects of an object transmitted in the form of a code to consciousness. The effects, in the final analysis, comprise a structure built by the mind, with the result that when we know an object, we

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144. Eddington, The Nature of the Physical World, p. 277.

know its structure. Writing in The Nature of the Physical World, Eddington says:

> It is necessary to keep reminding ourselves 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. Obviously, the message travels in code. When messages relating to a table are travelling in the nerves, the nerve-disturbance does not in the least resemble either the external table that originates the mental impression or the conception of the table that arises in consciousness. In the central clearing station the incoming messages are sorted and decoded, partly by intrinsic image-building inherited from the experience of our ancestors, partly by scientific comparison and reasoning. By this very indirect and hypothetical inference all our supposed acquaintance with and our theories of a world outside us have been built up. We are acquainted with an external world because its fibres run into our consciousness; it is only our own ends of the fibres that we actually know; from those ends we more or less successfully reconstruct the rest, as a paleontologist reconstructs an extinct monster from its footprints. 145

In part, however, it would seem that Eddington in this text is denying any identity between knowledge and the external world, when he says that the messages in the nerves relating to the table do not resemble either the external table or the conception of the table in consciousness. It is true that the messages do not resemble either table according to intrinsic nature, but they resemble both tables in their

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145. Ibid., pp. 277-278. Also, cf. New Pathways in Science, pp. 3-4.

structure. The structure of the table in the external world and the structure of the table in consciousness are identical. Ultimately, however, it must be admitted that structural knowledge is totally subjective. The mind imposes the structures upon the things of the external world, which, considered as known, constitutes the physical universe, but which, considered in itself, remains inscrutable.

Eddington, in saying that there is an identity between the structure of the external table and the table in consciousness, presupposes that the entities of physical science, describable in terms of pointer readings, must somehow have a counterpart in the external world. But this external world is beyond our apprehension, and science can make nothing of it. [146] Nevertheless, if the objectivity of science is to be safeguarded, something must at least be knowable, though actually not known, to mind. Since this 'something' knowable to mind remains inscrutable in its nature, then it, as the point of contact between the mind and the external table, cannot be the material of the table. Instead, it must belong to the domain of structures which permits structurability and perceptibility. Eddington speaks of material objects coming into contact with the mind in the following manner:

> Mr X knows a table; but the point of contact with his mind is not in the material of the

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146. Ibid., p. 253.

> table. Lightwaves are propagated from the table to the eye; chemical changes occur in the retina; propagation of some kind occurs in the optic nerves; atomic changes follow in the brain. 147

Just how the lightwaves, the chemical and atomic changes, which Eddington calls 'activity of matter,' become sensations in consciousness is not clear. But this is not his real concern. Instead, he seeks to recognize in the activity of matter the measures required for structure. He tries to see in the activity of matter a metrical description of certain aspects of the activity of the mind. In turn, the activity of the mind constitutes for him an insight into the complex of relations whose comparability provides the foundations of those measures. [148]

Accordingly, Eddington's structural and causal interpretation of the process of knowing reveals and affirms that all we can know of the objects and events in the inscrutable external world is their structure. In the structural process of knowing, messages are sent from the external world, enabling structures to be perceived. These messages reach the sensory fibres, where they are phrased in a code that has nothing in common with the original object except a structure [149] common to both the thing and consciousness. If what we know is primarily the content of consciouness,

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147. Eddington, The Nature of Physical World, pp. 267-268.

148. Ibid., p. 268.

149. Rosenbleuth, Arturo, Mind and Brain; A Philosophy of Science, Cambridge, Massachussetts, The MIT Press, 1970, p. 55.

it follows that what we know is primarily structure. When Eddington was asked the question, 'What sort of thing is it that we know?,' he affirmed that we know only structure, defined and investigated in the mathematical theory of groups.[150] In brief, he is saying that the only feature of the original object that reaches the intellect, when the corresponding mental processes decode the messages, is its structure. This agrees with the interpretation of Arturo Rosenbleuth, when he writes:

> The elements of sensory chains impose a series of transformations on the messages they receive from the material universe: (comparable to Eddington's inscrutable external world) the only feature of the original events that reaches us when the corresponding mental processes decode these messages is their structure. The only properties that are justified in attributing to material objects or events are those that pertain to their structure. 151

It follows, of course, that Eddington must deny the existence of secondary qualities in the physical universe. Since they do not have structural characteristics, they are meaningless, and accordingly, must be ascribed to the inscrutable external world. Not only are secondary qualities relegated to the realm of the unknown, but it also follows that one cannot infer from the coded messages anything whatsoever about the nature of the external world. Any

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150. Eddington, The Philosophy of Physical Science, p. 147.

151. Rosenbleuth, op. cit., p. 71.

speculation or statement about the nature of the external world is doomed to be utterly meaningless. That which exists is the physical universe, and this universe is nothing more than the structure of the external world. In turn, this structure is identical with our conscious decodings and the contents of our consciousness.

If mind, as revealed by the structural process of knowing, is the first and most direct thing in our experience, it follows that the rest of our knowledge is only inference from the effects of objects present in consciousness in their structural form. The external world becomes an inference from the structures it presents to the mind. In this inferential manner, the external world is ultimately known, but known only obliquely through structures that might be compared to a cryptogram. [152] In another place, Eddington compares this knowledge of the external world to the knowledge of a palaeontologist with respect to an extinct species, when he writes:

> We are acquainted with an external world because its fibres run into our consciousness; it is only our own ends of the fibres that we actually know; from those ends we more or less successfully reconstruct the rest, as a palaeontologist reconstructs an extinct monster from its footprints. 153

Eddington's position on structural knowledge and

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152. Eddington, New Pathways in Science, pp. 8-9. Cf. Stebbing, op. cit., pp. 104-105.

153. Eddington, The Nature of Physical World, p. 278.

the external world resembles closely the position of Bertrand Russell. For Russell, the objects of the material universe are inferred from their effects on the eyes, photographic plates and other instruments. Similarly, he maintains that we can know nothing of an object's intrinsic nature, but only its structure, inferred from the maxim "same cause, same effect". [154] The physical universe shares with the sensible world a similar structure, after the manner of the structural properties of a gramaphone record and the music it plays. [155]

To understand further Eddington's position, let us return briefly to the comparison of structure with the Aristotelian and Thomistic concept of 'form'. Just as form

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154. Russell, Bertrand, An Outline of Philosophy, New York, The World Publishing Co., Meridian Books, 1963, p. 163.

155. Russell, Bertrand, The Scientific Outlook, London, George Allen and Unwin Ltd., 1962, p. 84. "The most that can be known, and that only on the most hopeful view, is that there are certain relations in the physical world which share certain abstract logical characteristics with the relations that we know. The characteristics which they share are those that can be expressed mathematically, not those that distinguish them imaginatively from other relations. Take for example, what there is in common between the gramaphone record and the music that it plays; the two share certain structural properties which can be expressed in abstract terms, but they do not share any properties that are obvious to the senses. In view of their structural similarity, the one can cause the other. Similarly, a physical world sharing the structure of our sensible world can cause it, even though it may resemble it in nothing except in structure".

serves as the medium through which we have knowledge of the external world, [156] so too does structure. In either case, the knowledge is knowledge by way of inference. Objects in the external world, as they exist there, remain beyond our comprehension, but they take on an existence in the mind after the manner of form, impressed species, or, in Eddington's terms, after the manner of 'structure'. Consequently, as Yolton writes, "the sensible form, like Eddington's structure, is both in the object and in the observer's experience". [157]

Eddington finds yet another way of upholding the relation of structural knowledge to the external world when he considers the communicability of this knowledge. [158] The similarity of structures in the experiences of different individuals makes it possible for structural knowledge to be communicated. The similarity must be based on a neutral ground, or a common element in consciousness independent of

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156. Yolton, op. cit., p. 53.

157. Ibid., p. 53.

158. Eddington, The Philosophy of Physical Science, pp. 208-209. Also, cf. New Pathways in Science, p. 10: "...as soon as we commit ourselves to the recognition of other minds than our own, we are led to the conception of an external domain (physical space and time) to contain the inferential objects of our combined knowledge. Among these inferential objects are the nerve fibres and brain cells where (as the decipherment of the cryptogram progresses) the sources of communication between the objects of this external world and an individual consciousness are found to be located".

individual differences. This neutral ground or common element is none other than the external world. The externality intimated by the similarity of structure in individual consciousness brings together the many worlds of these consciousnesses. [159]

Accordingly, for Eddington, knowledge of the intrinsic nature of things is impossible. The only known elements constitute a pattern of interlocking present in consciousness. Since the immediate object of the knowing mind is consciousness itself, and since the structures constructed by the mind are subsumed in consciousness as sensations and sense-data, the only real world that is known is this world of structures in consciousness. Our investigation of the external world consists in the quest for these structures. [160]

In acquiring knowledge of the external world, the senses are traditionally seen as playing an essential role. They are conceived as the doors to intellectual knowledge. In Eddington's theory of knowledge, however, the senses are seen as mere instruments to be acted upon by what he calls the "basal entities". In these entities, are the observable phenomena analyzed by physics, and known only through their structural properties. [161] The senses are of the same status

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159. Eddington, The Nature of the Physical World, pp. 283-284.

160. Eddington, The Mathematical Theory of Relativity, p. 41.

161. Eddington, New Pathways in Science, p. 258.

as the instruments used by the physicist, their chief characteristic being that of selectiveness. The senses select or sift the material for consciousness from the objective world. The senses are reduced to a sensorial equipment with which the observer observes, while the intellect becomes the equipment with which the observer formulates the results of observation. Insofar as the knowledge acquired by observation is selective, it is simultaneously subjective. The selection is subjective to the extent that it depends on our sensory and intellectual equipment. [162]

Accordingly, things as objects of knowledge are selected both by the intellect and the senses. Instead of the object being given to the mental act of knowing, it is selected and interpreted to form structure before even being perceived as a thing. Eddington is maintaining that the external thing selected and referred to as an object is not existentially given, but cognitively given, in experience. The external thing is interpreted and revealed in terms of structures. As Roy Wood Sellars puts it, knowing in such a perspective becomes a "selective and interpretative act which claims to manifest the object". [163]

Moreover, for Eddington, the generalizations of physical science are formed not only from a systematic

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162. Eddington, The Philosophy of Physical Science, p. 17.

163. Sellars, op. cit., p. 77.

examination of the data furnished by observation, but also from an analysis of the methods and equipment used in observation. [164] The knowledge acquired from this analysis is very secure and compelling in character. "Generalizations that can be reached epistemologically have a security which is denied to those that can only be reached empirically". [165] Epistemology thereby becomes a source of knowledge with respect to the external world. Knowledge of the physical universe need no longer begin with the assumption that a sensation makes us aware of something in the external world different from the sensation. It is the structures of sensation in different consciousnesses which provide the logical starting-point of physical science. [166] More precisely, it is the external world as interpreted through structures that is the logical starting point of physical science. In addition to group-structures, we are aware of non-structural qualities in consciousness. The awareness of these non-structural qualities, however, becomes the point of departure for the invention of something that is structured. In short, structural knowledge is the starting-point for the whole of Eddington's philosophy of science. [167]

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164. Eddington, The Philosophy of Physical Science, p. 18.

165. Ibid., p. 19.

166. Ibid., p. 215.

167. Witt-Hansen, op. cit., p. 100.

DOCTRINE OF STRUCTURE AND DUALISM: APPEARANCE-REALITY, MIND-MATTER

Eddington, in reviewing Bertrand Russell's book, The Analysis of Matter, expressed his gratefulness to Russell for providing him with a clear understanding of the fundamental importance of structure as the only element of the external world that we can know. [168] Russell's work helped Eddington to realize that we can know nothing about the nature of the ultimate elements except the way in which they are woven together. The concept of structure provided Eddington with an insight into the old dualistic problem of reality and appearance, matter and mind. Eddington, following Russell's affirmations on this subject, asserted that the shortcomings of traditional philosophy, in providing an adequate solution to the problem, were caused by its failure to realize the dominant role of structure in our acquisition of knowledge. Eddington quotes Russell's Introduction to Mathematical Philosophy, first published in 1919, to show that there is already in Russell's philosophy a germinal stage of the doctrine of structure that affords an escape

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168. Eddington, Arthur Stanley, "New Books", review of Bertrand Russell's book, The Analysis of Matter, in Philosophy, Vol. 3, 1928, p. 93.

from dualism. [169] From the initial conception of structure in Russell, Eddington embarked on the enterprise of demonstrating how a more fully developed theory of structural knowledge could resolve the problem of dualism.

In this theory, Eddington upheld a structural representation of our perceptions of an external world. He conceived structure as the medium that makes possible our knowledge of the external world. Because of a similarity of structure, a group of sensations in one mind can be like a group of sensations in another. [170] The similarity of

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169. Russell, Bertrand, Introduction to Mathematical Philosophy, London, Allen and Unwin Ltd., 1938 (first published, 1919), p. 61: "There has been a great deal of speculation in traditional philosophy which might have been avoided if the importance of structure, and the difficulty of getting behind it, had been realized. For example, it is often said that space and time are subjective, but they have objective counterparts; or that phenomena are subjective, but are caused by things in themselves, which must have differences inter se corresponding with the differences in the phenomena to which they give rise. Where such hypotheses are made, it is generally supposed that we can know very little about the objective counterparts. In actual fact, however, if the hypotheses as stated were correct, the objective counterparts would form a world having the same structure as the phenomenal world...In short, every proposition having a communicable significance must be true of both worlds or of neither; the only difference must lie in just that essence of individuality which always eludes words and baffles description, but which for that very reason is irrelevant to science". Cf. Eddington, The Philosophy of Physical Science, p. 152.

170. Eddington, The Philosophy of Physical Science, p. 142.

structure is supported by the postulate of a common external world. Accordingly, the mind, through structure, extends beyond itself and its perceptual content to the external world, which underlies structure as a postulate. Within this context, Eddington is able to say:

> The fact that structural knowledge can be detached from knowledge of the entities forming the structure, gets over the difficulty of understanding how it is possible to conceive a knowledge of anything which is not part of our minds. [171]

The doctrine of structure becomes a viable solution to the problem of dualism, for "so long as the knowledge is confined to assertions of structure, it is not tied down to any particular realm of content". [172] Insofar as Eddington conceives of structure as independent of any particular content, he upholds a kind of neutral monism that overcomes the sharp contrast between reality and appearance, matter and mind, thereby rendering the opposition between them obsolete and meaningless. As he says:

> The recognition that physical knowledge is structural knowledge abolishes all dualism of consciousness and matter. Dualism depends on the belief that we find in the external world something of a nature incommensurable with what we find in consciousness; but all that physical science reveals to us in the external world is group-structure, and group-structure is also to be found in consciousness. When we take

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171. Ibid., p. 143.

172. Ibid., p. 143.

> structure of sensations in a particular consciousness and describe it in physical terms as part of the structure of an external world, it is still a structure of sensation. 173

Whether what we know is appearance or reality, that is, an "out-there" with an independent existence, is a meaningless question, for what we know is structure and not what it is a structure of. There is no dualism between the object "out-there," as the source of knowledge, and the sense-data or idea in the mind, for both are reducible to structure, and structure is all that we know. Dualism arises when we move from an epistemological perspective to a supposedly independent, existential perspective, as if the latter could be meaningful outside the former. The Philosophy of Physical Science, explains how Eddington sees the whole problem of dualism as voided. It reads:

> Let us denote by X (equivalent to the external world) the entity of which the physical universe is the structure, and distinguish the small part Xs known to be of sensory nature from the remainder Xu of which we have no direct awareness. It may be suggested that there remains a dualism of Xs and Xu equivalent to the old dualism of consciousness and matter; but this is, I think, a logical confusion involving a switch over from the epistemological view of the universe as a theme of knowledge to an existential view of the universe as something of which we have to obtain knowledge. Structurally Xu is no different from Xs, and to give meaning to the supposed dualism we have to imagine a supplementary non-structural

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173. Ibid., p. 150.

> knowledge of Xu revealing its unlikeness to Xs. We have to suppose that a direct awareness of Xu, if we could possess it, would show that it was not of sensory nature. But the supposition is nonsense; for if we had the supposed direct awareness of Xu, it would ipso facto be a sensation in our consciousness. 174

This resolution of the problem is based on the assumption that certain characteristics of physical things are reproducible in another medium, namely, in the sensory data used to interpret them. These reproducibles comprise patterns of interlocking, order, organization, and structure. The mind, which is the first thing that consciousness experiences, reproduces the structures of physical things within consciousness. These structures within consciousness, as the object of knowledge, constitute the only meaningful reality, insofar as the external world can be nothing more than these structures. Physical things, encountered through sensation, do not reach the intellect as physical things, but as structural patterns of the reproduced physical things. Eddington is identifying the data of perception and the whole knowable object with the external physical world. This identification is made possible by the reproducibility of the essential characteristics of physical things, namely, their structures. Not only are these structures reproduced in the intellect, they are reproduced in the sensory data

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174. Ibid., pp. 150-151. Words in parenthesis are mine.

as instruments of interpretation and organs providing the content of consciousness. In brief, with the reduction of both reality and mind, including sense consciousness, to structure, no problem of dualism is even possible. The problem of dualism only arises when the external world is postulated as different from, and of a nature incommensurable with, what is found in consciousness. From Eddington's viewpoint, this postulate is without foundation. [175]

In conclusion, it might be added that Eddington achieved this solution on the presupposition that elements of the scientific world conform with those of the familiar world, despite the fact that in his earlier works, he seemed to indicate that there are elements of the scientific world that lack counterparts in the familiar world. However, the seeming discrepancy disappears in the light of a more thorough analysis, as presented by John Yolton in the following:

> But even though every element in the scientific story does not have a counterpart in the familiar story (...), the scientific as well as the familiar story is controlled by certain interpretative patterns of the mind. Since the end product in both cases is the "peculiar interpretation of the code messages transmitted along the nerves" into the mind, since the same basic

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175. Eddington resolves the further dualism of mind versus brain in a similar manner: A sensation has, as its immediate correlative, a brain-event. Both are essentially one and the same, but operate in different realms: sensation, in the peculiar realm of sensible qualities; and brain-event, in the realm of physical events common to the whole of the physical world. Cf. Broad, C.D., "Sir Arthur Eddington's The Philosophy of Physical Science", a review of Eddington's book, in Philosophy, Vol. 15, No. 59, p. 308.

> categories of interpretation are at work in both stories, the relation between the two worlds would seem to arise by science starting with common sense, refining its process of analysis so far that it constructs entities far removed from the starting point, but entities which are taken as aspects (structural features) of an objective world. The process back to the familiar world is made by the realization that the interpretations science has placed upon its data have themselves been directed by specific categories at work as much in the familiar as in the scientific worlds. 176

DOCTRINE OF STRUCTURE AND THE CONCEPT OF REALITY

Our common concept of reality, when considered from the viewpoint of the doctrine of structure, requires special attention. With "X" standing for the external world, Eddington poses the question: "What is X when it is not a sensation in any consciousness known to us? "The right answer," he says, "is probably that the question is meaningless". [177] In posing the question, Eddington is asking: Does th e external world have an existence of its own? Is there, within the context of the doctrine of structure, such a thing as a reality independent of the observer's mind? In replying that the question is probably meaningless, Eddington is saying that his doctrine of structure obviates the problem entirely.

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176. Yolton, op. cit., pp. 43-44.

177. Eddington, The Philosophy of Physical Science, p. 151.

Eddington's remarks concerning the notion of reality betray a twofold pull within him, namely, the pull of the physicist with his adherence to hard fact, and the pull of the philosopher with his recognition that facts are valueless without adequate interpretation. The pull of the philosopher, independent of the physicist, could have drawn him towards some nebulous conception of reality, dissociated from the concrete, but the pull of the physicist asserted itself to provide a balance, as manifested in the following statement:

> I am afraid of this word Reality, not connoting an ordinarily definable characteristic of the things it is applied to but used as though it were some kind of celestial halo. 178

Nevertheless, though Eddington tried to maintain an objective conception of reality, the subjective was inclined to predominate.

The subjective aspect is anticipated in his emphasis on epistemology and the a priori as the key to knowledge in physical science, especially in the light of relativity theory. Against this background, reality becomes for him a reality constructed by the mind from the entities that come to the observer through instruments that are selective in their nature. These entities are from the external world, which Eddington calls "mind-stuff". "The stuff of the world" he says, "is mind-stuff". [179] Reality in these terms, is

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178. Eddington, The Nature of Physical World, p. 282.

179. Ibid., p. 276.

obviously shaped and determined by the categories and methodology used by the observer. The subjectivity of this conception of reality is pressed to an extreme when he says that a thing is said to be real "if it is the goal of a type of inquiry to which one personally attaches importance". [180]

DOCTRINE OF STRUCTURE IN PHYSICAL KNOWLEDGE

This subjectivity is supported by his claim that much of observationally derived knowledge can be predicted and inferred from an examination of the methodological tools of the physicist, together with an analysis of certain pervasive, primitive categories of thought. Reality becomes a product of the categories of thought and the methodological tools of the physicist, and is reducible to a schedule of pointer readings, electrons, and protons. This mental reality is rivalled by a "more comfortable kind of 'concrete' reality - something too inert and stupid to be capable of forging an illusion". [181] 'Concrete' reality shadows the subjective reality of electrons, protons and pointer readings, which assume a symbolic character derived from the constructive activity of the mind. The masses, velocities, energy, protons, electrons, assigned to objects in an a priori manner, are those free creations of the human mind that have proven

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180. Ibid., p. 283.

181. Ibid., p. 281.

useful for the formation of theories and concepts with respect to experience. [182] In short, reality is subjective insofar as it originates in the sensory and intellectual equipment of the subject; it is the observer who makes it. [183]

Despite this subjective conception, Eddington tries to uphold the objectivity of reality. Through his doctrine of structure, he seeks to show how observational knowledge relates to a world beyond observation. His concern for objectivity, in the face of his subjectivism, manifests itself in these words:

> So far as I can see, we find ourselves 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 - though, of course, they are not purely subjective. 184

This objectivity is made possible through the external world postulated by the doctrine of structure. In his Space, Time, and Gravitation, he maintained that an objective reality can be attained through the combination of all points of view stemming from the different content of different consciousnesses. Through this combined viewpoint, we are to learn the nature of the real world of physics. [185]

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182. Kemeny, John, A Philosopher Looks at Science, New York, Toronto, D. Van Nostrand Co. Inc., 1959, p. 158.

183. Witt-Hansen, op. cit., p. 90.

184. Eddington, New Pathways in Science, p. 292.

185. Eddington, Arthur Stanley, Space, Time, and Gravitation; An Outline of the General Theory of Relativity, Cambridge University Press, 1920, p. 182.

The bringing into focus of all the points of view, afforded us by reality, gives us objective reality. In other words, the objectively real, becomes the product of a synthetic merging of all points of view. This synthesis of different viewpoints gives rise to the external world of physics. It is to this common external world that Eddington refers, when he speaks of "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 viewpoint, now with another".[186] The external world can be considered objective reality insofar as it not proper to one individual consciousness, but common to all consciousnesses. As Eddington says, "The external world of physics is thus a symposium of the worlds presented to different viewpoints".[187]

To the extent that Eddington identifies the external world with objective reality, he may be said to belong to the realistic school of thought. Nevertheless, this external world, considered in itself, remains, for him, unknown. All that physics has to report concerning the nature of the external world is that "something unknown is doing we don't know what".[188] When for instance we see an elephant sliding

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186. Eddington, The Nature of the Physical World, p. 284.

187. Ibid., p. 284.

188. Ibid., p. 291.

down a hill, the impression of the bulkiness of the elephant which we experience 'presumably has some direct counterpart in the external world, but this counterpart must be of a nature beyond our apprehension, and science can make nothing of it'. [189] The common objective reality of the external world supports our experience, but exists beyond or outside it.

This concept of objective reality, however, which is recognized epistemologically to be present to scientific knowledge, should not be confused with the concept of the objective universe which we acquire in an a posteriori manner. The objective universe, acquired in an a posteriori manner, designates the material universe independent of the mind. The objective reality of the external world, of which we have been speaking, is not to be identified with the material universe. On the contrary, Eddington sees it as a "spiritual world". [190]

In summary, we may say that although Eddington's conception of scientific knowledge is strongly subjective, he has sought to establish the objectivity of science through his doctrine of structure. This endeavour may be better appreciated in the light of Arthur Lovejoy's words, who, writing in a similar vein, says:

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189. Ibid., p. 253.

190. Eddington, The Philosophy of Physical Science, p. 69.

> The atarting-point of the argument for physical realism...is the plain man's normal and reasonable belief that the processes of nature do not stop when he stops noticing them. It is not the "outerness" of the object perceived, when it is perceived, but the persistence of something which is in some manner connected with what is perceived, during the inter-perceptual intervals, that is the primary natural postulate out of which the belief in an external world, in objects which exist though they are not given in experience, arises. 191

Despite the sophisticatinn of this theory of physical knowledge, Eddington upholds "the plain man's normal and reasonable belief...in an external world," of which Lovejoy speaks.

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191. Lovejoy, Arthur, The Revolt Against Dualism; An Inquiry Concerning the Existence of Ideas, 2nd ed., The Paul Carus Lectures, Series 2, La Salle, The Open Court Publishing Co., 1960, p. 333.

CHAPTER IV

EVALUATION AND ASSESSMENT OF THE DOCTRINE OF STRUCTURE

Before the beginning of the modern era, philosophy and science were conceived and thought of without any distinction whatsoever. St. Thomas Aquinas, indeed, used these terms interchangeably because for him, the scientific inquiry was, when it was at its best, philosophical. It did not aim simply at the empiriological knowledge gained through controlled observation and measurement of the physical world, but rather at knowledge of the very being and essential structure of things. [192] The attractiveness of this conception at the time was so great that the preoccupation of starting-points and subject-matter was subsumed under philosophical analysis. Frequently problems, whether empiriological or not, were approached and solved practically by the methods of the ontological science of philosophy. During this time, the empiriological and physico-mathematical sciences belonged to the same category; they were in the custody of philosophy. However, insofar as philosophical analysis extended itself to include areas of physico-mathematical investigation, it

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192. Aquinas, Thomas, The Division and Methods of the Sciences; Question V and VI of his Commentary on the De Trinitate of Boethius, translated with introduction and notes by Armand Maurer, Toronto, The Pontifical Institute of Medieval Studies, 1953, pp. viii-ix.

imposed an ontological perspective on this domain of knowledge. As a result, the science of the day was inclined to make assertions of an ontological character that were alien to a properly physico-mathematical investigation.

With the dawn of the modern era, all this began to change. The philosophical approach within physical science was no longer acceptable, for it failed to achieve results, and accordingly, modern man revolted against the physics of the medieval ages. With this revolt against the physics of the medieval ages, the empiriological and physico-mathematical sciences gradually established themselves as distinct scientific ways of knowing, and their scope and methods were carefully defined. [193] In essence, the separation of philosophy and science began when the distinction was made between the 'know how' and 'know why' in investigation. Science switched its allegiance from a philosophical milieu beyond its ken to immediate brute facts afforded by its own methods. The close bond between science and the philosophy of the ancients and the medievals was thereby broken. Nevertheless, the question of starting-points for, and essential differences between,science and philosophy remained a source of dispute that has continued down to the present.

Today, however, there is certainly a clearer view of the distinction between science and philosophy; there is

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193. Ibid., p. xi.

a more precise delineation of their respective fields of concern. Despite the fact that there is little agreement as to what the distinction between the two is, no person today would think of equating them. This can be attributed in large measure to men who are devoted to the advancement of learning as a whole, whether scientific or philosophical. For the most part, these are scientists who are interested in discovering new frontiers of science and in understanding its methods. They are men who endeavour to appraise the achievement of modern science, and to establish the philosophical presuppositions of scientific theories, hypotheses, and axioms.

In other words, scientists have created their own philosophy. After the intellectual capital provided by seventeenth century philosophers was exhausted by nineteenth century scientists, the scientists of the present century turned to science itself for enlightenment in pursuit of scientific endeavour. Specifically, they turned to an examination of the presuppositions and methods of science, from which emerged philosophies of science and philosophies of the physical world.

CLARIFICATION OF STARTING-POINTS

Eddington was one of the first to develop a philosophy in the manner described. His effort in advancing the a priori knowledge acquired epistemologically from the

examination of the methods and instruments used by physical science led to the novelty of his doctrine of structure in clarifying the respective starting-points of physical science and philosophy. If there is one thing that this doctrine has shown and clarified concerning the relationship between science and philosophy and their respective areas of concern, it is the dilineation of the critical starting-point of science as distinct from the metaphysical starting-point of a realist philosophy.

Eddington maintained that science, along with its correlative physical philosophy, must start from knowledge acquired through the examination of the methods and equipment used by the observer in the process of observation. The doctrine of structure brings out the aspect that physical science, coupled with a sound epistemology, does not start by affirming an existent entity of which we somehow have to obtain knowledge. Physical science does not commence by seeking to establish whether such an entity exists outside or inside the mind, or whether it exists at all. Given that the physical universe is a theme of a specified body of knowledge, we do not start from an existing entity but rather from knowledge, specifically a structural knowledge proper to ourmode of knowing the physical universe. In other words, physical science starts from structure, which is the medium whereby we claim to have knowledge of the physical universe, and from which we infer the existence of the external world.

It is knowledge of structure on the level of sensation in consciousness which constitutes the starting-point of physical science. 'The occurrence of identical, or closely related, structures of sensation in different consciousness provides the logical starting-point of physical science". [194] And again, treating the concept of structure, Eddington says that "the starting-point of physical science is knowledge of the group-structure of a set of sensations in a consciousness". [195]

With this doctrine of structure, the lines between physical science and the ontological science are clearly drawn. The doctrine strengthens the orientation of physical science toward the observable and measurable; the subject for analysis is sought by means of physical operations that effect possibilities of observation and measurement. The philosophy generated by physical science's self-examination of its methods, tools and equipments serves to explicate and justify the very affirmations of physical science. The elements or entities with which physical science deals, are grasped inside a system of phenomenal regularities, circumscribed by the observable system [196] and expressed algebraically in

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194. Eddington, The Philosophy of Physical Science, p. 215.

195. Ibid., p. 148. Underlining is mine.

196. Simon, Yves, "Maritain's Philosophy of Science," in St. John's University Studies, p. 33.

terms of group-structure. These phenomenal regularities never disengage themselves from the observational system that circumscribes them. They are the events which permit the structuralization of knowledge and the inferring of existence of material objects.

Whereas physical science starts its investigation from the observation of the phenomenal regularities and recurrencies occurring within consciousness in the form of structural concepts and sensations, ontological science starts from the basic and primitive assertion of an existing being by common sense-experience. Ontological science starts from the activity of the senses which provides us with perceptions not produced by, or in any way resulting from, the processes of research or investigation. Instead, these perceptions arise from the normal operation of the sense-organs in the ordinary life of the organism.

Eddington did not deny that physical science must start from experience, and to this extent, a kind of momentary empiricism may be ascribed to him. This empiricism, however, would only be valid if it recognized the existence of a material world behind the experience. The existence of the material world is not an important issue for Eddington. His philosophy of physical science, at best, assumes it and leaves it as implicit. It is not his concern, but the concern of ontological philosophers who investigate the intelligible aspects and elements of being. He is not particularly

interested in whether or not regularities and recurrencies reveal essences to the scientific mind. Instead, he is interested in the basic affirmations provided by these phenomenal recurrencies and regularities as structured in consciousness. The basis of all phenomenal recurrencies and regularities is a scheme or structural pattern of symbols connected by mathematical equations. [197] This scheme or pattern is the starting-point for science, from which all science progresses. Not only that, but this scheme or pattern constitutes what is meant by 'physical reality'. As a skeleton-scheme of symbols, or structure, physical reality is, accordingly, hollow enough [198] to contain anything whatever the physicist or the welder of symbols, the mathematician, puts into, or allocates to, it to become substantial.

The recognition of structure as the starting-point of physical science enabled Eddington to generalize and apply it to the whole of scientific inquiry. Scientific investigation must start from the structured data of sensations contained in the minds of conscious being. With this as his starting-point, he had to maintain that we can only know a physical world external to the thinking self by way of inference from the data within consciousness. [199]

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197. Eddington, New Pathways in Science, p. 313.

198. Ibid., pp. 313-314.

199. Eddington, "Physics and Philosophy," in Philosophy, Vol. 8, No. 29, January 1933, p. 33.

Insofar as Eddington did not conceive the object of physical science to extend beyond structure as constituting physical reality, physical science was, for him, vested with a security and necessity that it otherwise would not have. It also led him to think that all knowledge, whether physical or not, including any authentic knowledge of an ontological character, must have a similar starting-point. Moreover, bearing in mind that Eddington belonged to a milieu that was inclined to view science as objective and philosophy as subjective, it might be said that his thought provided a basis for both the objectivity of science and the subjectivity of philosophy. The starting-point that he ascribed to physical science strengthened the objectivity of the scientific world, insofar as it was confined to mere pointer readings, group-structures expressible in algebraic symbols, and to the entities created by the mind, namely, electrons, protons, positrons, etc. At the same time, it strengthened the subjective world of philosophy which annexed the colors, sounds, scents,tastes, touches, bodily feelings, "as forming the subjective content of the cogitations of the individual mind". [200]

IMPORTANCE OF STRUCTURE AS A PRINCIPLE OF ORGANIZATION

Eddington envisages his structural system as

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200. Whitehead, Alfred North, Science and the Modern World, Lowell lectures, 1925, New York, The New American Library of World Literature Inc., Mentor Books (copyright 1925, 1962), p. 132.

extending beyond physical science to the organization that properly belongs to every field of learning. The various disciplines need to study their structures in terms of symbols, signs, signals, which, though not necessarily mathematical, must be subject to the rule of permutation, that is, to the rule of change in the order of sequence of elements or objects in a series.

Within physical science, structuralization has proven useful at the quantal level where observation seems to be futile as far as knowing the activity of sub-atomic particles is concerned. Although atoms can be bombarded, splitting them into many constituents, they retain the structure that accounts for their organization. This structure can only stem from the mind's structural allocation of symbols to the constituent entities. The pattern of structures assigned to the physical world follows the endogenous laws of construction in the mind.

Similarly, in any field of learning, an analysis of the structure or organization of our cognitive activity can help to provide us with the knowledge of things we seek to know. After all, form, structure, or principle of organization, is proper to every level of experience, and when this form, structure, or principle of organization is made manifest, it should aid in knowing the thing experienced. The basis of all structural affirmations concerning knowledge and reality, whether expressible in algebraic or linguistic symbols, lies

in the natural aspiration and movement of the mind to reduce the multiplicity of the given to a unity. This unity with respect to multiplicity constitutes the most generic notion of form, structure or order.

No less than the simplest molecule of living matter, the atom, whether it is considered as hypothetical or real, has been shown to have a very definite structure. A knowledge of this structure has enabled the scientist to predict the behaviour of the atom under controlled conditions. Scientists today more than ever regard as vital the structural organization of the quantal particle, which is expressed in physico-mathematical terms. They have made an effort to discover the link between the quantal particles of matter through a process of bombardment within a machine called the accelerator. In shattering the neuclei of atoms, they can poke among the nuclear fragments and isolate them. Smaller than quanta, these fragments, known as "quarks," are believed to be the most elemental units of matter. Even on this level, however, the recognition of a kind of structure or pattern is seen as indispensable.

The wave-and-particle theory of the propagation of light, seemed at first sight to eliminate any notion of structure, for if matter could be viewed as having the form of a wave in one instance and the form of a particle in other, then matter itself appeared to be indeterminate, without any form or structure. But upon further reflection,

it was recognized that the notion of structure, as conceived by a philosophical physicist like Eddington, was the very thing that made this ambivalent composition of matter possible. Neither the atomic system nor quantum mechanics professed to give us so much the building blocks of matter, whether they be reducible to waves, particles or anything else, as the organization or structure of our knowledge of matter, or of matter as known. As a result, the emphasis today, for the physical scientist, is not so much on the quantitative entities out of which a physical universe is built, but on the structure required for the building of that universe. A morphic structure is seen as present on every level of matter, including the quantum and sub-quantum levels.

The notion of structure bears an analogy not only to form as a morphic principle in metaphysics but to the principle of existence. It is true that structure lends an essential determination to the constituent elements of matter, and as such, may be considered as form. But in addition, insofar as structure is seen as still present after an analytic breakdown of matter into its constituent elements, it can be viewed as the scientific counterpart of existence over and above the essence of a thing. To the extent that the comparison is valid, the notion of existence in metaphysics may be recognized as providing an heuristic principle for physical science in guiding it beyond the realization of the constituent elements of the universe to

the awareness of structure and its significance.

Apart from the special role that Eddington assigned to the doctrine of structure in a scientific knowledge of the physical universe, it plays a role in perception generally that renders possible the very survival of a living organism. It is by means of the structure built into perception that living things are able to adapt to their external environment. As Wartofsky says:

> The structuralization and ordering of perception is necessary and important for it is a means whereby the organism is able to fit its actions to its environment; it permits ordered actions with respect to meeting the survival needs of the organism. The ordering of experience becomes an instrumentality of success in action. 201

Finally, let us note that Eddington's doctrine of structure restored to physical science a realism of which it had been bereft, pursuant to an exclusively analytic approach that left us with a view of physical reality as so much dismantled machinery. Speaking of this analytic kind of science, he writes:

> When we analyze the picture into a large number of particles of paint, we lose the aesthetic significance of the picture. The particles of paint go into the scientific inventory, and it is claimed that <u>everything that there really was</u> in the picture is kept. But this way of keeping a thing may be much the same as losing it. The essence of a picture (as distinct from the paint) is arrangement. Is arrangement kept or lost? The current answer seems inconsistent. Insofar as

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201. Wartofsky, <u>op. cit.</u>, p. 34.

> arrangement signifies a picture, it is lost; science has to do with paint, not pictures. Insofar as arrangement signifies organization, it is kept; science has much to do with organization. Why should we (speaking now as philosophers, not scientists) make a discrimination between these two aspects of arrangement? The discrimination is made because the picture is no use to the scientist - he cannot get further with it. 202

It is now our task, however, to see whether the realism contributed by Eddington's doctrine of structure is an adequate realism or not. To do this, it is necessary to examine the metaphysical implications of the doctrine.

METAPHYSICAL IMPLICATIONS OF THE DOCTRINE OF STRUCTURE

It is evident that the physical world of Eddington is a mathematical one. He endeavours to construct a world that is conformable with, or adaptable to, mathematical formulae and structures, fitted to a group-system of symbols. His physical world is modelled upon logically interconnected mathematical symbols. As such, it is similar to that of Plato: It is a mathematically symmetrical world of forms intellectually constructed. Eddington fashions the stuff of the world out of pointer readings and sees the world, in its totality, as an aggregate of point-events. Between any two point-events, there exists a certain relation known as an

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202. Eddington, The Nature of the Physical World, p. 106.

interval. "Out of primary interval-relations of this sort an unlimited number of more complicated relations can be built up, describing various features of the state of the world". [203] If, in building a world that will be congruent and coherent with mathematical forms, the 'building materials are to be relations and relata, relations uniting the relata, and relata the meeting points of the relations,' [204] then the structure of such a world will be composed of operational symbols and will be based upon the possibility of weaving and interconnecting these symbols.

Ludwig Wittgenstein proceeded in a somewhat similar manner in his conception of a world reducible to the requirements of ordinary language. [205] Admittedly, Wittgenstein was more directly concerned with reality as such, and accordingly endeavoured to construct a real world of external things that could be expressed logically in symbols belonging to propositions and language. Nevertheless, just as his world is modelled upon logical interconnections of propositions that could be expressed in ordinary language, Eddington's world is modelled

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203. Witt-Hansen, op. cit., p. 25.

204. Eddington, The Nature of Physical World, p. 230.

205. Wittgenstein, Ludwig, Philosophical Investigations, part I, second edition, translated by G.E.M. Anscombe, Basil & Blackwell & Mott, Ltd., 1963, pp. 2eff.

upon the constructs of mathematical physics, wherein mathematical formulae are conceived as explanations and interpretations of the physical universe. Just as Wittgenstein's world is composed of the stuff of linguistic symbols, so too Eddington's world is composed of the stuff of pointer-readings.

Both in Wittgenstein's system of linguistic analysis and Eddington's doctrine of structure, the importance of operational symbols as the source of meaning comes to the fore. For Wittgenstein, they give meaning to his conception of a world constitutive of objects strung together and interconnected in some kind of network or web. This network or web, taken as a whole, constitutes what he calls the "state of affairs," the totality of which constitutes the world. [206] For Eddington, operational symbols give meaning to the mathematical structures in the capacity of the symbols to relate the structures to the material world. These operational symbols permit multiple possible ways in which mathematical physics can, through structures, provide us with the representational existence of things in the material world. Structures can be taken as representative of reality to the extent that the

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206. Wittgenstein, Ludwig, Tractatus-Logico-Philosophicus, new translation by D.F. Pears and B.F. McGuiness, London, Routledge and Keagan Paul (first German edition 1921) 1961, p. 13: "The totality of existing states of affairs is the world".

operational symbols of which they are composed are representative, though the reality represented remains essentially unknown.

Insofar as reality remains unknown, Eddington's world must be considered a world of pure context without content. In the final analysis, the symbolic characters of the structure, in their mathematically representative role, are empty. As Eddington says:

> ...the X's and Y's of our algebra and logic are empty of content unless they are interpreted to refer to this or that. That is to say, they are empty of factual content or of reference to experience or to the external world. 207

A resemblance can be seen not only with Wittgenstein in contemporary philosophy, but also with earlier philosophers like Descartes and Kant. Eddington's doctrine of structure endorses a pure quantification of essences in a manner similar to Descartes. Likewise, insofar as Eddington's structures constitute various possible ways in which reality may be represented, they bear a resemblance to the Kantian concept of possibles. All the properties of things, which belong to the traditional notion of essence, are relegated to the mind. Things exist outside the mind only in the form of structure, which is expressed within the mind through mathematical formulae and symbols. Ultimately, then, Eddington sees the physical

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207. Wartofsky, op. cit., pp. 99-100.

world as composed purely of mental entities, which exist in the mind as quantifiable and relational. For example, protons, electrons, phlogiston, aether, etc., are free creations of the mind, interpretable according to mathematical forms and structures.

Despite the claims of scientists under the watchful eye of the positivist that metaphysics has no heuristic value within science, it is evident in Eddington's doctrine of structure that an essentialistic metaphysics [208] is at work underneath. What is thinkable and imaginable can be represented by a structure describable in algebraic symbols and certified by mathematical affirmations through calculations and measurements. The thinkable and imaginable belong to the order of possibles or essences conceived within the mind.

Apart from any relational character of structures provided by the operational symbols of which the structures are composed, there is the substitutional role of the structures themselves in acting as a substitute for reality. The manner in which the symbols are weaved and connected, to constitute a mathematical world within the mind, supplies the continuous background of a physical world. "It is the connectivity of

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208. By 'essentialist metaphysics,' we mean a metaphysics that professes the primacy of essence over existence as a principle of being. The emphasis is on the principle that makes a thing to be what it is, namely, essence.

pointer-readings expressed by physical laws which supplies the continuous background that any realistic problem demands". [209] What concerns the physicist when he studies things is not so much whether a matter or a body is a man, a tree, a bag of iron, or a sack of potatoes, as whether a body is measurable, capable of being calculated and read on a scale. Accordingly, Eddington's implicit essentialist metaphysics can be gleaned from three aspects of his thought. First, essentialism manifests itself in his theory of world-building, the stuff of the world being mind-stuff; [210] the building materials are the elements of relations and relata, [211] constructed by the mind within consciousness. Secondly, it lies in his belief that physics is wholly concerned with a schedule of pointer-readings, cyclically interlocked in such a manner that through each term there runs an inscrutable nature, unknown to the mind. Thirdly, it lies in his belief that the world of physics represents symbolically this inscrutable background as well as the familiar world. [212]

In summary, Eddington maintains that what is in the mind, that which can be thought and imagined, can be expressed into reality in terms of algebraic symbols, which are

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209. Eddington, The Nature of Physical World, p. 255.

210. Ibid., p. 276.

211. Ibid., p. 230.

212. Stebbing, op. cit., p. 83.

structuralized and certified by mathematical formulations. The resultant structure constitutes the reality of things in the material world, though the real nature of these things, considered in themselves, beyond the range of theoretical reason and structuralization, remains unknowable. The world that Eddington conceives is built from the relation-structure given only in a physico-mathematical knowledge whose objects are pure constructs of the mind. These objects are, metaphysically speaking, 'entities' that have no existence independently of the mind; they are given a 'reality' by the mind, subsequent to the selection of materials by the mind and the sensory process. The world composed of these entities has no permanence; it changes with continuous progress in science. "The world which we have built from the relation-structure is no doubt doomed to be pulled about a good deal as our knowledge progresses". [213]

From the essentialism underlying Eddington's doctrine of structure, we can draw the following consequences. First of all, concerning the essence of matter, we may recall that the Greek atomists maintained that the smallest particles of matter are atoms, and that Plato conceived the smallest particles of matter to be simple geometric forms. In the 19th century, scientists viewed the supposedly smallest particle of matter, the atom, as itself composed of elementary particles, which

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213. Eddington, The Nature of the Physical World, p. 243.

were considered to be the only real existents of the physical world. [214] With the introduction of the quantum theory in the 20th century, physicists conceived these elementary particles of the atom in terms of probability, formulated according to mathematically expressible laws. [215]

Eddington, influenced by the latter development in science, views matter after the manner of Platonic forms or constructs of the mind. In his exposition of the philosophical implications of the theory of relativity, he tells us:

> It is perhaps a commonplace that, whatever may be the true nature of matter, it is the mind which from the crude substratum constructs the familiar picture of a substantial world around us. 216

Electrons and protons, as the constituents of matter, are products of the mind, out of which the mind constructs the so-called substantial world. These constituents of matter are not real in the sense of possessing an existence independent of the mind; rather, they are the mind's invention. As such, science has nothing to say about the actual nature of a physically existing atom, because for science the atom does

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214. Heisenberg, Werner, "Planck's Discovery and the Philosophical Problem of Atomic Physics," in On Modern Physics, essays by Werner Heisenberg, Max Born, Erwin Schrodinger and Pierre Auger, New York, Collier Books, The Crowell-Collier Publishing Co. (copyright 1961 by clarkson N. Potter) 1962, pp. 12-13.

215. Ibid., p. 17.

216. Eddington, Arthur Stanley, "The Meaning of Matter and the Laws of Nature according to the Theory of Relativity," in Mind, Vol. 29, 1920, p. 10.

not possess any nature beyond what can be found in symbolic interpretation and quantification. Consequently, the atom is considered to be a mere schedule of pointer-readings, a form which the mind manufactures and mathematically interprets to represent reality.

> The physical atom is, like everything else in physics, a schedule of pointer-readings. The schedule is, we agree, attached to some unknown background. Why not then attach it to something of spiritual nature of which a prominent characteristic is thought. 217

In a manner, therefore, reminiscent of Plato, Eddington conceives the atomic constituents of matter as belonging to an essential world of pure mental forms. As Heisenberg says:

> These smallest units of matter are not in fact physical objects in the ordinary sense; they are forms, ideas which can be expressed unambiguously only in mathematical language...Plato was convinced that his principle could be expressed and understood only in mathematical terms. 218

It is not surprising, then, to hear scientists talking about atoms and their constituents, not in terms of physical realities but, in terms of masses, instantaneous accelerations, conservative systems, all of which belong to the order of idealized essences in the mind. [219]

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217. Eddington, The Nature of the Physical World, p. 259.

218. Heisenberg, Werner, "Natural Law and the Structure of Matter," in Frontiers of Modern Scientific Philosophy, The Athens Meeting, 1964, London, Elsevier Publishing Company, 1966, p. 37.

219. Blackwell, Richard, Discovery in the Physical Sciences, Notre Dame, Notre Dame University Press, 1969, p. 93.

Although Eddington stipulates that atoms are real insofar as they are structurable, W.T. Stace maintains that, for Eddington, they have no real existence, as indicated in the following:

> That atoms are not inferences from sense-data means, of course, that from the existence of sense-data we cannot validly infer the existence of atoms. And this means that we cannot have any reason at all to believe that they exist. And that is why I propose to argue that they do not exist - or at any rate that no one could know it if they did and that we have absolutely no evidence of their existence. [220]

In accord with a basic essentialism, Eddington similarly reduces the notion of substance, taken as objective and an element of permanence, to a mere mental construct. He sees the traditional concept of substance as nothing more than "a projection of our sense-impressions outwards into the external world". [221] Substance, rigged out with the attributes of form, color, hardness, etc., which appeal to the senses and are so vivid in the mind, cannot be embodied in a legitimate conception of the substantial object itself. Substance, as traditionally conceived, can, accordingly be construed merely as a pictorial projection of sense-data by the mind into the external world. [222] For Eddington, substance, conceived as

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220. Stace, T.W., "Sir Arthur Eddington and the Physical World," in Philosophy, Vol. 9, 1934, p. 45.

221. Eddington, The Nature of the Physical World, p. 273.

222. Sellars, op. cit., p. 290.

something objective and as an element of permanence, is simply an illusion of the mind. He writes as follows:

> It was an illusion. Then why toy with it longer? These airy fancies which the mind, when we do not keep it severely in order, projects into the external world should be of no concern to the earnest seeker of truth. 223

Likewise, Eddington sees the concept of existence as nothing more than a part or a property of his mathematically constructed universe. In the light of no agreement as to its meaning, Eddington does not accept the notion of existence as having any real significance, and relegates it to a primitive form of thought. Symbols can be assigned to this form of thought to denote its truth-value. It can be structuralized to express something belonging to a universe, mathematically conceived. The epistemological approach in physical science does not require the attribution of real existence to things outside the mind. "It is an advantage of the epistemological approach," Eddington says, "that the question of attributing a mysterious property called 'existence' to physical universe never arises". [224]

As for the principle of causality, it similarly loses its ontological character in Eddington's world. It becomes a purely observational causality whereby, when we say E causes

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223. Eddington, The Nature of the Physical World, p. 318.

224. Eddington, The Philosophy of Physical Science, p. 157.

G, we mean, watch for the occurrences of E and you will observe the occurrences of G. In terms of mathematicizing this observational causality, we move on to what Anatol Rapoport calls 'manipulative causality,' wherein to say E causes F means, make E occur and you will observe F, or, prevent E from occurring and F will not occur. [225]

IDEALISM WITHIN A SCIENTIFIC THEORY OF KNOWLEDGE

The necessary correlative of essentialism in metaphysics is idealism in a theory of knowledge. By 'idealism' we refer to the position that when we know, we know only our own ideas present in the mind. He maintains that all we can know of the objective world is its structure, or the structure of the objective world as mirrored in our consciousness. It is absurd to presuppose that we observe the objective world as having material properties. Whatever is observed must ultimately be the content of our consciousness and accordingly non-material. Consequently, when we know something, all that we know is the content of consciousness. This content is reducible to structure, and the structures belong to the ideal order, that is, to the order of 'ideas,' in the traditional meaning of the word.

Eddington, properly speaking, refers to the 'idealism'

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225. Rapoport, Anatol, Operational Philosophy; Integrating Knowledge and Action, New York, J. Wiley, (copyright 1953) 1965, p. 58.

of science. In scientific knowledge, we behold a non-material domain underlying the physical world as a whole, but one that must not be thought of as distributed so that to each element of time and space there is a corresponding portion of spiritual substratum. Although, for the most part, the enquiry of science 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 a mental and spiritual nature. Apart from what is seen through these openings, we know no more than the veil. This does not, however, lead to pure subjectivism, for the objective world of my perception is also the world of perception. There is an external world which is not part of the mind of either of us, but a neutral ground wherein is located the basis of that experience which we hold in common. [226]

Things in the world are known, insofar as they exist in the mind as ideas, which are nothing more than essences divested and stripped of their characteristics and qualities. The ideas of structure are the only ideas that provide the physicist with the knowable properties of bodies, and these it provides in metrical form. They do not involve any actual participation of the knowing subject in the known object, considered as a thing with an independent existence outside

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226. Eddington, New Pathways in Science, pp. 322-332.

the mind. This is the inevitable consequence of starting a philosophy of science from the examination of knowledge. Admittedly, knowledge includes very definite conceptions of objects in the external world. But before science can begin to handle and confirm such conceptions, they must be replaced by conceptual quantities appearing from the results of physical measurements. [227] In keeping with the idealistic character of scientific epistemology, the act of acquiring knowledge entails the mind's actively making up for the deficiency of impressions by constructing relations between them, and thereby contributing to the formation of the experienced object. Moreover, certain relationships embodied in the perceived universe belong solely to the order of interconnections, with the result that they do not exist outside these interconnections. Spatial relations, for example, are not separable from time-relations, nor from those of mass or mutual movement, for they all exist in the mind as categories of thought. They are ideas produced by the mind in reflecting upon its knowledge of objects in the external world. [228]

The quantification of these ideas in the mind moves us into the realm of mathematics. The ideas as quantified, constituting the representational vehicle of the real, are

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227. Reyna, Ruth, The Philosophy of Matter in the Atomic Era, New York, Bombay, Asia Publishing House, 1962, p. 66.

228. Blackwell, op. cit., p. 21.

only expressible through mathematics, which describes the pattern of sensations and elucidates the group-structure of the elements of knowledge. The very symbols employed are ideas that the mind creates and substitutes for reality. Through symbols, what is represented by them is rendered communicable, to form our knowledge of the world. What is known, however, is not the world in itself, but our ideas of the world. Like the rationalist, who holds that we know only representational ideas, and the empiricist, who holds that we know only representational sense-impressions, Eddington maintains that we know only representational structures, and not the thing or object existing outside the mind.

The patent idealism of Eddington's position is an inevitable consequence of starting with knowledge itself in his effort to elaborate the theory of knowledge proper to physical science. Carried to its ultimate conclusion, his position would make it possible for a scientist to dispense with experiment and concentrate upon the structures of scientific knowledge alone for an understanding of the physical universe. As Sir James Jeans says:

> ...Eddington believes that 'all the laws of nature that are usually classed as fundamental can be foreseen wholly from epistemological considerations' and further that 'not only the laws of nature but also the constants of nature can be deduced from epistemological considerations, so that we can have a priori knowledge of them'. It follows that 'an intelligence unacquainted with our universe, but acquainted with the system of thought by

> which the human mind interprets to itself the content of its sensory experience, should be able to attain all the knowledge of physics that we might have attained by experiment. ...' 229

The axioms and postulates of a scientific theory of knowledge depend upon the idealization of experience in terms of interrelatedness of elements present in many different consciousnesses. Knowledge based upon the idealization of experience gives us only a picture, or more strictly a symbolic formulation, of an "external theatre of activity interacting with each individual consciousness". [230] A picture or a symbolic formulation of the external world is nothing but a representation or idea constructed by the mind, which the mind interprets for itself. Eddington's physical world is abstracted by the mind from a more comprehensive reality which is known only by inference from its effects upon the brain and consciousness. Admittedly, although it is constructed by the mind from relations and relata, it is, as given, embedded in a background of reality. [231] Nevertheless, this physical world remains freighted with idealism, as is evident from the following:

> Accordingly my subject of study becomes differentiated into the contents of many

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229. Jeans, James, Physics and Philosophy, London, Cambridge University Press, 1942, p. 74.

230. Eddington, New Pathways in Science, p. 281.

231. Ibid., p. 292.

> 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 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 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. 232

Despite a shade of realism that might be gleaned from this text, we recognize its patent idealism in attempting to derive the external world from consciousness.

If in scientific epistemology, being as the object of knowledge is reduced to a mere undisclosed principle of orderliness that masquerades as structure and guarantees the steadiness of the phenomenal regularities, then what can be said of the nature of man? What is man? From the subjective standpoint of Eddington, man is no more than a pure consciousness compounded by mental activities. Any response to inquiries concerning his nature lies in the domain of one's own consciousness. Eddington, from the view-point of his doctrine of structure, describes man as a bundle of pointer-readings, and the way things are going in physics, he conjectures that it is quite possible that science may finally declare man to be

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232. Eddington, The Nature of the Physical World, pp. 283-284.

no more than a fortuitous concourse of atoms, understood as nothing but 'unit characters'. [233] In a similar vein, Eddington sees physical science as reducing 'an elephant sliding down a grassy hillside' to 'a mass of two tons,' beyond which reduction nothing is known of the subject. [234] In these terms, man must be symbolized as a "Mr. X," since we know nothing of his real nature; it belongs to the inscrutable world. Our knowledge of him is only possible through inference. To describe man and to infer what he is, it is necessary to reduce him to pure symbols. The inference is from symbols immediately associated with sensations in one's mind to the symbols descriptive of Mr. X. The inferred concept of man is consequent upon a chain of stimuli in the external world starting from Mr. X and reaching ultimately the brain. [235] This manner of conceiving what man is, in the last analysis, reduces to a conception of man as pure mind or consciousness, for what is beneath these symbols are the contents of the mind, which the mind possesses and interprets. Speaking on this subject, Eddington writes:

> To know what there is about Mr. X...we must look not to a physical system of inference, but to that insight beneath the symbols which in our mind we possess. It is by this insight that we can finally reach an answer to the question, What is Mr. X? 236

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233. Ibid., p. 251.

234. Loc. cit.

235. Ibid., p. 270.

236. Ibid., p. 272.

Eddington adopts an operationalist approach in the development of his theory of knowledge. In the light of this approach, he charges that traditional philosophy offers no well-defined criteria for evaluating the relevance and importance of the different links in the chain of mental steps which lead from what one observes, perceives, or imagines, to what one concludes about what is. If what one observes is to correspond with what is in the mind, and if one is to be certain of their identity, then one needs criteria for evaluation and verification. Eddington's doctrine of structure endeavors to fulfill this role; it provides the criterion of truth for physical science, insofar as structure guarantees the identity between what one perceives and what is concluded concerning what is. As such, it performs a function in knowledge similar to Descartes' clear and distinct ideas.

Eddington's starting-point of science and philosophy is the presupposition that there are certain time-sequences in our experience. "The kind of datum," he says, "from which scientist and philosopher alike must start is exemplified by I-perceive-the-taste-of-an-apple". [237] The string of words indicates that such perception constitutes a unity of a particular kind, namely, the unity of a sequential occurrence. Subsequent concepts must be resolved into observable data and finally into measurable data expressed in algebraic symbols

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237. New Pathways in Science, p. 282. Also, cf. The Philosophy of Physical Science, pp. 203-208.

and mathematical forms. The resultant mathematico-physical world of science compares with Kant's order of appearances, beyond which lies the inscrutable external world of Kant's thing-in-itself.

With regard to this inscrutable external world, Eddington finds himself identifying it with consciousness. Speaking of an adversary, he writes:

> Does he regard consciousness as supernatural? The it is he who is admitting the supernatural. Or does he regard it as part of Nature? So do we. We treat it in what seems to be its obvious position as the avenue of approach to the reality and significance of the world, as it is the avenue of approach to all scientific knowledge of the world...We have associated consciousness with a background untouched in the physical survey of the world and have given the physicist a domain where he can go round in cycles without ever encountering anything to bring a blush to his cheek. 238

In other words, for Eddington, the external world belongs to the spiritual realm or to the ideal sphere, as Herbert Dingle indicates in the following:

> ...the nature of the external world is a phase waiting for a content, and these are entities waiting to be placed in the external world. What could be simpler than to bring them together and to regard the external world as having the nature of life, consciousness, spirit? 239

Eddington's identification of the external world with consciousness is reminiscent of Fichte's identification of the

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238. Eddington, The Nature of the Physical World, p. 348.

239. Dingle, op. cit., p. 39.

world with the ego. The resemblance, however, is by no means total. Eddington was not prepared to say that it was consciousness that was represented symbolically by the entities of the physical world. [240] The external world is divided into the subjective and the objective. The subjective external world, known through physical investigation only in the form of structures, remains in the final analysis inscrutable. It is the objective external world that is identifiable with life, consciousness, spirit. We have direct knowledge of this world through non-metrical investigation, in the form of our sensations, thoughts and emotions, these being in consciousness and thereby constituting the first and most direct things of our experience.

In his last major work, Fundamental Theory, where he attempted to present his ideas as constituting a coherent system, Eddington was very explicit in seeing the external world in terms of pure numbers. [241] The prominent role that he assigned to number is recognized by Yolton in the following words:

> Like the Pythagoreans, Eddington was strongly attached to numbers and saw in them a strange power for explaining the world...Eddington argued that a close analysis of numbers and their relation to non-numerical reality leads

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240. Ibid., p. 40.

241. Eddington, Fundamental Theory, pp. 139, 265-266.

> to valid insights concerning the structure of the world...Hence, numbers stood as symbols not only of the phenomenal world which they help to form, but also of the non-phenomenal world revealed in our structural knowledge. 242

In a similar vein, Edmund Whittaker says that ultimately Eddington, in keeping with a four-dimensional concept of body, sees 'the external world as isomorphous with the square of quaternion algebra'. [243] This structural isomorphism between Thought and Nature provided Eddington with a justification for all fields of knowledge and experience, in addition to a means of harmonizing the world of everyday experience with the world of physics. [244] What is in Nature and in Thought are one and the same, namely, structure as isomorphic. Objects of knowledge are numerically identical and isomorphic with the data of knowledge. The original structure in the external world is reproduced as a structure of sensations in consciousness. Through this similarity or isomorphism of structure within and without, the problem of dualism is resolved for Eddington.

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242. Yolton, op. cit., p. 92.

243. Edmund Whittaker, "Eddington's Theory of the Constant of Nature," in The Mathematical Gazette, Vol. 29, No. 282, Oct. 1945, p. 137.

244. Ibid., p. 144.

CONCLUSION

Eddington's philosophy helps to clarify the relation between philosophy and physical science. His doctrine of structure, culminating in his declaration of an isomorphism between thought and nature has aided an understanding of this relation. In this endeavour, he has tried to steer a middle course between empiricism and rationalism, and at the same time assimilate any useful concepts that stem from one or the other. British empiricism, however, predominates, as would be expected from his English origin and background, but not to the exclusion of rationalism. His preoccupation in trying not to disregard the role of sense-data and impressions in the initial movement of scientific inquiry is evidence of his empiricism. On the other hand, his insistence upon the mind as actively constructing and selecting materials for a scientific synthesis manifests his rationalism.

Indeed, this simultaneous presence of empiricism and rationalism in his thought may be seen as an indication of the difficulty he experienced in trying to resolve the problem of dualism. In claiming that the structure of things is the same as the structure of sensations in consciousness, he does not really solve the problem, for he is still within the realm of thought or ideas; nor does the mathematization of these structures provide any remedy. A structuralized universe, created by the mind, does not lead us to an affirmation

of the real as having an independent existence outside the mind.

The failure of Eddington's doctrine of structure to provide an adequate solution to the problem of dualism stems from a wrong starting-point for his philosophy, namely, the starting-point of knowledge. If what we first know is that which is in the mind, i.e., sense-data, ideas and structures, there is no possibility of our knowing things existing outside the mind. Admittedly, the doctrine of structure, which issues in positing an isomorphism between thought and nature, is meant to obviate this difficulty. In the final analysis, however, the doctrine entails subsuming everything within the mind, and accordingly, does not allow for the independent existence of things outside the mind.

Hume's theory of knowledge commenced with sense-impressions, that is, with the position that what we first know are pure sense-impressions. Likewise, Descartes affirmed that what we first know are our own ideas. For both, as a result, supporting an affirmation of the existence of external objects remained a problem. Similarly, Eddington affirmed that the external world is unknown and unknowable, for all that we know is structure. In each instance, the root-cause of the difficulty in upholding the existence of the external world is to be found in the common starting-point of their theories of knowledge, namely, knowledge itself, from which they could not move beyond the thinking self.

In Eddington's endeavour to abolish the dualism of matter and consciousness, something of the traditional notion of the 'idea' is retained. He asserts, first of all, that physical knowledge is structural knowledge; and then he maintains that the physical world, which is the object of physical knowledge, is the structure of the external world outside individual consciousnesses. This is rendered possible, insofar as he conceives the original structure in the external world to be reproduced as a structure of sensations in consciousness, with a resultant commensurability between the two. In brief, the commensurability of structure replaces the representational value of the traditional 'idea'.

Nevertheless, Eddington's philosophy remains essentially idealistic. It is true that he maintained the existence of a spiritual objective world, but his scientific mind moved him ultimately to put this world on the same plane as his physical world, which was essentially subjective. In the final analysis, therefore, his physical and spiritual worlds are both products of the mind's activity. The spiritual world is built out of symbols taken from our own personality, just as the physical, scientific world is built out of the metrical symbols of the mathematicians.

Eddington could have eliminated any notion of a spiritual objective world without jeopardizing his philosophy of physical science. His retention of it would appear to stem from extra-scientific forces within him, namely, a pietism

coupled with a tendency toward mysticism. It was his religious convictions that urged him to cling to a spiritual world wherein lies man's ethical and religious beliefs, a kind of world where man can exercise his responsibility as a human being. [245] On the other hand, the objectivity of this spiritual world was inclined to take second place in his mind to the subjectivity of a scientific world that emerged from his acceptance of relativity and quantum theory. In the light of these theories, he was forced more and more to look at physical phenomena in terms of subjective structure, and to put more emphasis upon the subject as an observer and eventually upon the purely constructive activity of the human mind.

But the spiritual continued to maintain a hold over him, with the result that his thought, taken in its totality, moves between the polarities of religious conviction and scientific insight. [246] He sees the world of everyday life, or the world good enough for man to live in, as a spiritual world. Besides this, there is the world of the scientist, that is, the physical world, which is observed, investigated and analyzed. Accordingly, the actual world beyond the physical world of science is not, in the final analysis, the thing-in-itself of Kant, but rather, the pragmatically real; it is a

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245. Eddington, The Nature of the Physical World, p. 324.

246. Ibid., pp. 281-282, 325, 339.

world stemming from our own ingenuity and designed to work for our own good and ends. [247] Epistemologically considered, it is as subjective ultimately as the physical world of science.

Before Eddington's doctrine of structure could resolve the dualistic problem of matter/consciousness and appearance/reality, there would have to be a further clarification of the logical relation between physics and psychology. Eddington, like Descartes and Kant, is locked up in the mind's constructs; he needs some criterion to guarantee that the structure of objects in the external world is the same as the structure of sensations in consciousness. The problem is compounded by the fact that it is not clear to what extent his psychological knowledge is dominated by the forms of thought which govern physics.

Nevertheless, credit must be given Eddington for a criticism, analysis and justification of physical theories that enabled him to attempt laying the foundations for connecting science with other fields of human inquiry, namely, the philosophical, ethical and religious. Given the possibility of this connection, Eddington's thought makes room for further development in these areas from the perspective of scientific thought. Recognizing that physical theories give way in time to others, he was not so much concerned with supporting this or that theory, but in the ongoing development of thought behind

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247. Reyna, op. cit., p. 65.

theories, toward a further realization of meaning in the world.

In summary, we have reached the following conclusions: First, Eddington's doctrine of structure does not offer a tenable solution to the dualistic problem of consciousness/matter and appearance/reality, since it cannot account for the independent existence of objects in the external world. Secondly, the need of the doctrine of structure for a kind of demigod to provide a criterion or principle of verification whereby the mind could pass from thought to reality is yet another indication in the history of philosophy of the futility of commencing with knowledge itself as the basis for knowledge. The realist is again vindicated in affirming that being is the first object of the intellect, and accordingly in maintaining that philosophy must respect from the beginning the independent existence of things outside the mind. Finally, the failure of the doctrine of structure to move beyond mind underscores the need of physical science, not to stop short with phenomena but, to approach through phenomena an understanding of the real nature of things.

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ABSTRACT

One of the most persistent problems for both philosophers and scientists has been the apparent dualism of matter and mind. As philosophy and science developed along their respective lines, this problem took the form of a confrontation between the physical world of physical science and the everyday world of common sense-experience. Moreover, when classical physics was replaced by modern physical theories, the problem became more sophisticated and came into sharper focus.

Sir Arthur Stanley Eddington, amidst all the major discoveries of modern physics, more immediately those of the relativity and quantum theory, was faced with this problem. Initially, Eddington perceived the problem to be nothing more than one resulting from conflicting world-views, namely, his Victorian world, a world revealed by the senses, as opposed to the world revealed by modern physics, a world of entities constructed by the mind. The real problem, however, which he later recognized, lay deeper, as his research on physical science revealed. He saw that this problem could only be resolved through the construction of a viable epistemology suitable for both science and philosophy. This epistemology would provide an answer to the concommitant question as to whether physical science extends beyond the order of phenomena or appearances to the order of real being.

Eddington's epistemology emerged from his scientific

investigations into relativity, quantum theory, and group-structure. From these investigations, he was led to formulate his doctrine of structure and his consequent philosophy of structuralism and selective subjectivism. By way of philosophical assistance, he found that the Kantian a priori provided him with an idealistic theory of knowledge and a rationalistic approach to the theories of modern physics. He also found that the causal theory of perception suited his structural explanation of knowledge, and likewise, that operationalism was at home within his system.

Eddington conceived structure as an aggregate of symbols which are connected and interrelated. In the process of knowing, he assigned to structure a role similar to Aristotle's concept of form. The structure of things and the content of consciousness are basically the same; thought and nature are isomorphic or homologous. Given this role of structure, Eddington went on to affirm that there is no fundamental difference between matter and consciousness, between the thing existing outside the mind and the idea of the thing in the mind. In this manner, Eddington saw the problem of dualism as resolved; for him, thought and nature have the same structure; they are homologous.

Eddington affirmed the existence of an external world on the basis of a structure that is perceived in common by all consciousnesses. This community of structure in diverse consciousnesses points to a common origin beyond consciousness,

namely, the external world. It is a world that must be postulated as existing, if the communicability of knowledge is to be explained, but it is a world whose nature remains unknown.

Eddington's elaboration of his doctrine of structure helps to clarify for us the starting-point of physical science as opposed to the starting-point of a realist philosophy. As for Eddington, science, along with its correlative philosophy of science, starts from knowledge through the examination of the methods and equipments of science. A realist philosophy, on the other hand, starts from the basic and primitive assertion of an existing being by common sense-experience.

In the light of a realist position, the metaphysical shortcomings of Eddington's epistemology become evident. His physical world is a world built out of mind-stuff, that is, a world solely constructed by the mind. It is a world of pure context without content. The principle of causality loses its ontological meaning and is reduced to the notion of mere regularities and recurrences of events, that is, to a kind observational causality. Matter is viewed as nothing more than a construct of the mind, similar to a Platonic form. Likewise, the notion of substance is reduced to a mental construct.

Eddington's doctrine of structure was meant to aid an understanding of the relation between philosophy and physical science. The isomorphism that he posited between thought and nature was to have resolved the problem of dualism for both

philosophy and science. But the doctrine was inadequate, for it failed to account for the existence of things apart from the mind. He started from knowledge and remained locked inside it. His doctrine of structure needed a kind of demigod as a principle of verification whereby the mind could pass from thought to reality.